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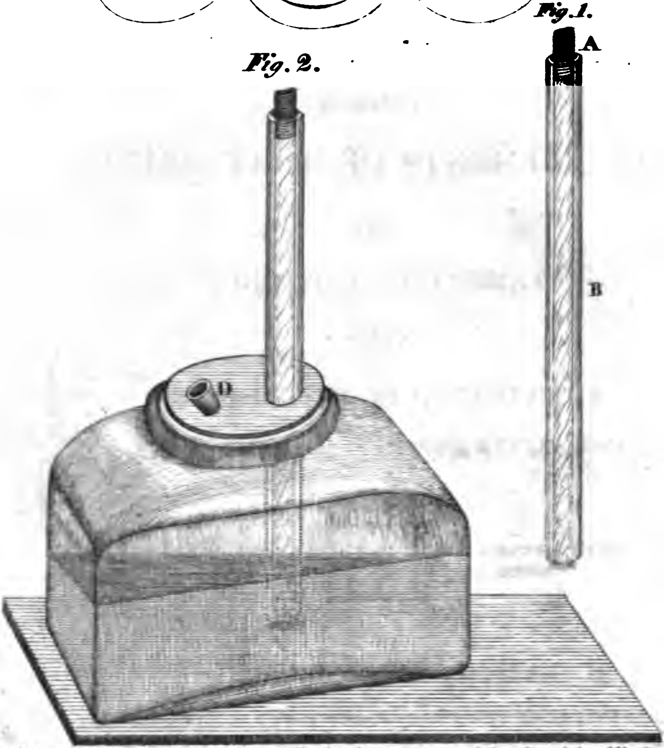

Fig. 1. A The Coil of Platina wire. — B the glass tube containing the wick. Fig. 2. the Lamp complete. — D the tube for charging.

Flameless Lamp.

See Page 323.

Designed by Dr. J. L. Comstock.

Delineated & Engraved by I. Bamford.

CONVERSATIONS
ON
CHEMISTRY;
IN WHICH
THE ELEMENTS OF THAT SCIENCE
ARE
FAMILIARLY EXPLAINED
AND
ILLUSTRATED BY EXPERIMENTS,
AND SIXTEEN COPPER-PLATE ENGRAVINGS.

THE EIGHTH AMERICAN FROM THE SIXTH LONDON EDITION, REVISED, CORRECTED AND ENLARGED.

TO WHICH ARE NOW ADDED,

EXPLANATIONS OF THE TEXT—QUESTIONS FOR EXERCISE—DIRECTIONS FOR SIMPLIFYING THE APPARATUS, AND A VOCABULARY OF TERMS—TOGETHER WITH A LIST OF INTERESTING EXPERIMENTS.

BY DR. J. L. COMSTOCK. [illegible]

* * *

[illegible]

HARTFORD:
OLIVER D. COOKE.
1822.

Conn. Library

DISTRICT OF CONNECTICUT, ss.

L. S. BE IT REMEMBERED, That on the twenty ninth day of December, in the forty sixth year of the Independence of the United States of America, Oliver D. Cooke of the said District hath deposited in this office the title of a Book, the right whereof he claims as proprietor, in the words following, to wit, "Conversations on Chemistry: in which the elements of that science are familiarly explained and illustrated by experiments, and sixteen copperplate engravings. The eighth American from the sixth London edition, revised, corrected and enlarged. To which are now added, explanations of the text, questions for exercise, directions for simplifying the apparatus, and a vocabulary of terms; together with a list of interesting experiments. By Dr. J. L. Comstock." In conformity to the act of the Congress of the United States, entitled, "An act for the encouragement of learning, by securing the copies of Maps, Charts and Books, to the authors and proprietors of such copies, during the times therein mentioned."

CHAS. A. INGERSOLL,
Clerk of the District of Connecticut.

A true copy of Record, examined and sealed by me,
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Clerk of the District of Connecticut.

P. B. GOODSELL, PRINTER.

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OF THE AMERICAN EDITOR.

THE familiar and agreeable manner in which the "Conversations on Chemistry" are written, renders this one of the most popular treatises on the subject which has ever appeared. The elegant and easy style also, in which the authoress has managed to convey scientific instruction is peculiarly adapted to the object of the work.

In some respects, however, the English edition may be considered as objectionable. A book designed for the instruction of youth, ought if possible to contain none but established principles.

Known and allowed facts are always of much higher consequence than theoretical opinions. To youth, particularly, by advancing as truths, doctrines which have arisen out of a theory not founded on demonstration, we run a chance of inculcating permanent error.

In these respects we think that Mrs. Bryan has not been sufficiently guarded. The brilliant discoveries of Sir Humphrey Davy, and his known eminence as a Chemical Philosopher, seem in many instances to have given his opinions an authority, which in the mind of the writer, superseded further investigation. Indeed inferences are sometimes drawn from these opinions which they hardly warrant. Under this view of the subject, a part of the notes are designed to guard the pupil against adopting opinions which he will find either contradicted, or merely examined by most chemical writers. In addition to this, I have made such explanations of the text as I thought would assist the pupil in understanding what he read.

In attempting to make this science popular, and of general utility, it is of great importance that the experiments come within the use of such instruments as are easily obtained. I have therefore given such directions on this subject as my former experience, as a lecturer, with a small apparatus, taught me to believe would be of service.

The questions, I believe, will be found to involve whatever is most important to be known throughout the work.

The list of experiments was chiefly made up without referring to books; some few of them, however, are copied from Parke, Accum, &c.

HARTFORD, CT. Jan. 1, 1822.

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PREFACE.

IN venturing to offer to the public, and more particularly to the female sex, an introduction to Chemistry, the author, herself a woman, conceives that some explanation may be required; and she feels it the more necessary to apologise for the present undertaking, as her knowledge of the subject is but recent, and as she can have no real claims to the title of chemist.

On attending for the first time experimental lectures, the author found it almost impossible to derive any clear or satisfactory information from the rapid demonstrations which are usually, and perhaps necessarily, crowded into popular discourses of this kind. But frequent opportunities having afterwards occurred of conversing with a friend on the subject of chemistry, and of repeating a variety of experiments, she became better acquainted with the principles of that science, and began to feel highly interested in its pursuit. It was then that she perceived, in attending the excellent lectures delivered at the Royal Institution, by the present Professor of Chemistry, the great advantage which her previous knowledge of the subject, slight as it was, gave her over others who had not enjoyed the same means of private instruction. Every fact or experiment attracted her attention, and served to explain some theory to which she was not a total stranger; and she had the gratification to find that the numerous and elegant illustrations, for which that school is so much distinguished, seldom failed to produce on her mind the effect for which they were intended.

Hence it was natural to infer, that familiar conversation was, in studies of this kind, a most useful auxiliary source of information; and more especially to the female sex, whose education is seldom calculated to prepare their minds for abstract ideas, or scientific language.

As, however, there are but few women who have access to this mode of instruction; and as the author was not acquainted with any book that could prove a substitute for it, she thought that it might be useful for beginners, as well as satisfactory to herself, to trace the steps by which she had acquired her little stock of chemical knowledge, and to record, in the form of dialogues, those ideas which she had first derived from conversation.

But to do this with sufficient method, and to fix upon a mode of arrangement, was an object of some difficulty. After much hesitation, and a degree of embarrassment, which, probably, the most competent chemical writers have often felt in common with the most superficial, a mode of division was adopted, which, though the most natural, does not always admit of being strictly pursued—it is that of treating first of the simplest bodies, and then gradually rising to the most intricate compounds.

It is not the author's intention to enter into a minute vindication of this plan. But whatever may be its advantages or inconveniences, the method adopted in this work is such, that a young pupil, who should only recur to it occasionally with a view to procure information on particular subjects, might often find it obscure or unsatisfactory; for its various parts are so connected with each other as to form an uninterrupted chain of facts and reasonings, which will appear sufficiently clear and consistent to those only who may have patience to go through the whole work, or have previously devoted some attention to the subject.

It will, no doubt, be observed, that in the course of these Conversations, remarks are often introduced, which appear much too acute for the young pupils, by whom they are supposed to be made. Of this fault the author is fully aware. But, in order to avoid it, it would have been necessary either to omit a variety of useful illustrations, or to submit to such minute explanations and frequent repetitions, as would have rendered the work tedious, and therefore less suited to its intended purpose.

In writing these pages, the author was more than once checked in her progress by the apprehension that such an attempt might be considered by some, either as unsuited to the ordinary pursuits of her sex, or ill-justified by her own imperfect knowledge of the subject. But, on the one hand, she felt encouraged by the establishment of those public institutions, open to both sexes, for the dissemination of philosophical knowledge, which clearly prove that the general opinion no longer excludes women from an acquaintance with the elements of science; and, on the other, she flattered herself, that whilst the impressions made upon her mind, by the wonders of Nature, studied in this new point of view, were still fresh and strong, she might perhaps succeed the better in communicating to others the sentiments she herself experienced.

The reader will soon perceive, in perusing this work, that he is often supposed to have previously acquired some slight knowledge of natural philosophy, a circumstance, indeed, which appears very desirable. The author's original intention was to commence this work by a small tract, explaining, on a plan analogous to this, the most essential rudiments of that science. This idea she has since abandoned, an elementary work on Natural Philosophy having appeared just as the first edition of the "Conversations on Chemistry" was preparing for the press. Her intended tract, however, was actually written, and subsequent considerations have lately induced her to offer it to the public.

Sulphurated Hydrogen Gas.---Harrowgate, or Hydro-sulphurated Waters.---Phosphorus.---Decomposition of Phosphorus.---History of its Discovery.—Its Combustion in Oxygen Gas.—Phosphoric Acids.---Phosphorus Acid.---Eudiometer.---Combination of Phosphorus with Sulphur.—Phosphorated Hydrogen Gas.-- Nomenclature of Binary Compounds.---Phosphoret of Lime burning under Water.

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CONVERSATIONS
ON
CHEMISTRY.

CONVERSATION I.

ON THE GENERAL PRINCIPLES OF CHEMISTRY.

Mrs. B. As you have now acquired some elementary notions of NATURAL PHILOSOPHY, I am going to propose to you another branch of science to which I am particularly anxious that you should devote a share of your attention. This is CHEMISTRY, which is so closely connected with Natural Philosophy, that the study of the one must be incomplete without some knowledge of the other; for, it is obvious that we can derive but a very imperfect idea of bodies from the study of the general laws by which they are governed, if we remain totally ignorant of their intimate nature.

Caroline. To confess the truth, Mrs. B., I am not disposed to form a very favourable idea of chemistry, nor do I expect to derive much entertainment from it. I prefer the sciences which exhibit nature on a grand scale, to those that are confined to the minutiæ of petty details. Can the studies which we have lately pursued, the general properties of matter, or the revolutions of the heavenly bodies, be compared to the mixing up of a few insignificant drugs? I grant, however, there may be entertaining experiments in chemistry, and should not dislike to try some of them: the distilling, for instance, of lavender, or rose water......

Mrs. B. I rather imagine, my dear Caroline, that your want of taste for chemistry proceeds from the very limited idea you entertain of its object. You confine the chemist's laboratory to the narrow precincts of the apothecary's and perfumer's shops, whilst it is subservient to an immense variety of other useful purposes. Besides, my dear, chemistry is by no means confined to works of art. Nature also has her laboratory, which is the universe, and there she is incessantly employed in chemical operations. You are surprised, Caroline; but I assure you that the most wonderful and the most interesting phenomena of nature are almost all of them produced by chemical powers. What Bergman, in the introduction to his history of chemistry, has said of this science, will give you a more just and enlarged idea of it. The knowledge of nature may be divided, he observes, into three periods. The first is that in which the attention of men is occupied in learning the external forms and characters of objects, and this is called *Natural History.* In the second, they consider the effects of bodies acting on each other by their mechanical power, as their weight and motion, and this constitutes the science of *Natural Philosophy.* The third period is that in which the properties and mutual action of the elementary parts of bodies are investigated. This last is the science of CHEMISTRY, and I have no doubt you will soon agree with me in thinking it the most interesting.

You may easily conceive, therefore, that without entering into the minute details of practical chemistry, a woman may obtain such a knowledge of the science as will not only throw an interest on the common occurrences of life, but will enlarge the sphere of her ideas, and render the contemplation of nature a scene of delightful instruction.

Caroline. If this is the case, I have certainly been much mistaken in the notion I had formed of chemistry. I own that I thought it was chiefly confined to the knowledge and preparation of medicines.

Mrs. B. That is only a branch of chemistry which is called Pharmacy; and though the study of it is, no doubt, of great importance to the world at large, it belongs exclusively to professional men, and is therefore the last that I should advise you to pursue.

Emily. But, did not the chemists formerly employ themselves in search of the philosopher's stone, or the secret of making gold?*

---

* The Alchymists had in view three great objects of discovery, viz. 1st. The *Elixir of health;* by the use of which the lives of men might be protracted to any desirable length, or their mortality prevented. 2nd. The *universal solvent,* or a liquid which should dissolve every other substance. This it was supposed would lead to the grand discovery, viz. 3rd. The *making of gold,* or finding the *philosopher's stone.* That men of sound and discriminating minds on other subjects, should have spent their whole lives in pursuits so chimerical, is to us wonderful indeed. But our wonder ceases in some degree, when we are told that the doctrine of transmutation, &c. was founded on a *Theory,* which, in the 12th century, was considered as plausible, as we consid-

Mrs. B. These were a particular set of misguided philosophers, who dignified themselves with the name of Alchemists, to distinguish their pursuits from those of the common chemists, whose studies were confined to the knowledge of medicines.

But since that period, chemistry has undergone so complete a revolution, that, from an obscure and mysterious art, it is now become a regular and beautiful science, to which art is entirely subservient. It is true, however, that we are indebted to the alchemists for many very useful discoveries, which sprung from their fruitless attempts to make gold, and which, undoubtedly, have proved of infinitely greater advantage to mankind than all their chimerical pursuits.

The modern chemists, instead of directing their ambition to the vain attempt of producing any of the original substances in nature, rather aim at analyzing and imitating her operations, and have sometimes succeeded in forming combinations, or effecting decompositions, no instances of which occur in the chemistry of Nature. They have little reason to regret their inability to make gold, whilst, by their innumerable inventions and discoveries, they have so greatly stimulated industry and facilitated labour, as prodigiously to increase the luxuries as well as the necessaries of life.

Emily. But I do not understand by what means chemistry can facilitate labour; is not that rather the province of the mechanic?

Mrs. B. There are many ways by which labour may be rendered more easy, independently of mechanics; but mechanical inventions themselves often derive their utility from a chemical principle. Thus that most wonderful of all machines, the Steam-engine, could never have been invented without the assistance of chemistry. In agriculture, a chemical knowledge of the nature of soils, and of vegetation, is highly useful; and, in those arts which relate to the comforts and conveniences of life, it would be endless to enumerate the advantages which result from the study of this science.

---

er many of ours at the present day, viz. That a perfect metal consisted of *quicksilver* and *sulphur;* these, when pure and united, formed gold. That all other metals contained a quantity of dross, which prevented the particles of these two substances from uniting. If therefore, this dross could be got rid of in the other metals, *gold* would be the result. They believed also, that nature herself favoured this operation. Thus Friar Roger Bacon, in his Mirror of Alchymy, says, "I must tell you, that nature alwaies intendeth and striueth to the perfection of gold; but many accidents comming between, change the mettalls, &c." See his Book printed in 1597, Chap. ii. C.

Caroline. But pray, tell us more precisely in what manner the discoveries of chemists have proved so beneficial to society?

Mrs. B. That would be an injudicious anticipation; for you would not comprehend the nature of such discoveries and useful applications, as well as you will do hereafter. Without a due regard to method, we cannot expect to make any progress in chemistry. I wish to direct your observations chiefly to the chemical operations of Nature; but those of Art are certainly of too high importance to pass unnoticed. We shall therefore allow them also some share of our attention.

Emily. Well, then, let us now set to work regularly. I am very anxious to begin.

Mrs. B. The object of chemistry is to obtain a knowledge of the intimate nature of bodies, and of their mutual action on each other. You find therefore, Caroline, that this is no narrow or confined science, which comprehends every thing material within our sphere.

Caroline. On the contrary, it must be inexhaustible; and I am at a loss to conceive how any proficiency can be made in a science whose objects are so numerous.

Mrs. B. If every individual substance were formed of different materials, the study of chemistry would, indeed, be endless; but you must observe that the various bodies in nature are composed of certain elementary principles, which are not very numerous.

Caroline. Yes; I know that all bodies are composed of fire, air, earth, and water; I learnt that many years ago.

Mrs. B. But you must now endeavour to forget it. I have already informed you what a great change chemistry has undergone since it has become a regular science. Within these thirty years especially, it has experienced an entire revolution, and it is now proved, that neither fire, air, earth, nor water, can be called elementary bodies. For an elementary body is one that has never been decomposed, that is to say, separated into other substances; and fire, air, earth, and water, are all of them susceptible of decomposition.

Emily. I thought that decomposing a body was dividing it into its minutest parts. And if so, I do not understand why an elementary substance is not capable of being decomposed, as well as any other.

Mrs. B. You have misconceived the idea of *decomposition;* it is very different from mere *division.* The latter simply reduces a body into parts, but the former separates it into the various ingredients, or materials, of which it is composed. If we were to take a loaf of bread, and separate the several ingredients of which it is made, the flour, the yeast, the salt, and the water, it would be very different from cutting or crumbling the loaf into pieces.

Emily. I understand you now very well. To decompose a body is to separate from each other the various elementary substances of which it consists.

Caroline. But flour, water, and other materials of bread, according to your definition, are not elementary substances.

Mrs. B. No, my dear; I mentioned bread rather as a familiar comparison, to illustrate the idea, than as an example.

The elementary substances of which a body is composed are called the *constituent* parts of that body; in decomposing it, therefore, we separate its constituent parts. If, on the contrary, we divide a body by chopping it to pieces, or even by grinding or pounding it to the finest powder, each of these small particles will still consist of a portion of the several constituent parts of the whole body: these are called the *integrant* parts; do you understand the difference?

Emily. Yes, I think, perfectly. We *decompose* a body into its *constituent* parts; and *divide* it into its *integrant* parts.

Mrs. B. Exactly so. If therefore a body consists of only one kind of substance, though it may be divided into its integrant parts, it is not possible to decompose it. Such bodies are therefore called *simple* or *elementary*, as they are the elements of which all other bodies are composed. *Compound bodies* are such as consist of more than one of these elementary principles.

Caroline. But do not fire, air, earth, and water, consist, each of them, but of one kind of substance?

Mrs. B. No, my dear; they are every one of them susceptible of being separated into various simple bodies. Instead of four, chemists now reckon upwards of forty elementary substances. The existence of most of these is established by the clearest experiments; but, in regard to a few of them, particularly the most subtle agents of nature; *heat*, *light*, and *electricity*, there is yet much uncertainty, and I can only give you the opinion which seems most probably deduced from the latest discoveries. After I have given you a list of the elementary bodies, classed according to their properties, we shall proceed to examine each of them separately, and then consider them in their combinations with each other.

Excepting the more general agents of nature, heat, light, and electricity, it would seem that the simple form of bodies is that of a metal.*

Caroline. You astonish me! I thought the metals were only one class of minerals, and that there were besides, earths, stones, rocks, acids, alkalies, vapours, fluids, and the whole of the animal and vegetable kingdoms.

Mrs. B. You have made a tolerably good enumeration, though I fear not arranged in the most scientific order. All these bodies, however, it is now strongly believed, may be ultimately resolved into metallic substances.† Your surprise at this circumstance is not singular, as the decomposition of some of them, which has been but lately accomplished, has excited the wonder of the whole philosophical world.

But to return to the list of simple bodies—these being usually found in combination with oxygen, I shall class them according to their properties when so combined. This will, I think, facilitate their future investigation.

Emily. Pray what is oxygen?

Mrs. B. A simple body; at least one that is supposed to be so, as it has never been decomposed. It is always found united with the negative electricity. It will be one of the first of the elementary bodies whose properties I shall explain to you, and, as you will soon perceive, it is one of the most important in nature; but it would be irrelevant to enter upon this subject at present. We must now confine our attention to the enumeration and classification of the simple bodies in general. They may be arranged as follows:

CLASS I.

Comprehending the imponderable agents, viz.

HEAT OR CALORIC,
LIGHT,
ELECTRICITY.

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* No actual discovery makes this probable. It is supposing that all the gases, as oxygen, hydrogen, &c. as well as phosphorus, sulphur, and carbon and several other substances are in part composed of a metal, and yet not one among this number are known to have metallic bases. C.

† Three of the alkalies only are known to have metallic bases. C.

CLASS II.

Comprehending agents capable of uniting with inflammable bodies, and in most instances of effecting their combustion.

OXYGEN,
CHLORINE,
IODINE.*

CLASS III.

Comprehending bodies capable of uniting with oxygen, and forming with it various compounds. This class may be divided as follows:

DIVISION I.

HYDROGEN, *forming* water.

DIVISION 2.

Bodies forming acids.

NITROGEN, . . . *forming* nitric acid.
SULPHUR, . . . *forming* sulphuric acid.
PHOSPHORUS, . . *forming* phosphoric acid.
CARBON, ... *forming* carbonic acid.
BORACIUM, . . . *forming* boracic acid.
FLUORIUM, ... *forming* fluoric acid.
MURIATIUM, . . *forming* muriatic acid.

DIVISION 3.

Metalic bodies forming alkalies.

POTASSIUM, . . . *forming* potash.
SODIUM, ... *forming* soda.
AMMONIUM, . . . *forming* ammonia.
LITHIUM, ... *forming* lithina.†

DIVISION 4.

Metallic bodies forming earths.

CALCIUM, *or metal forming* lime.
MAGNIUM, ... *forming* magnesia.
BARIUM, ... *forming* barytes.

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* A majority of the most learned Chemists, it is believed, have doubted whether Chlorine and Iodine were supporters of combustion, any farther than they contain oxygen. C.

† This fourth alkali was discovered by Mr. Arfundson, a Swedish chemist, so recently as the year 1818.

STRONTIUM, . . . *forming* strontites.
SILICIUM, ... *forming* silex.
ALUMIUN, ... *forming* alumine.
YTTRIUM, ... *forming* yttria.
GLUCIUM, ... *forming* glucina.
ZIRCONIUM, . . . *forming* zirconia.[*]

DIVISION 5.

Metals, either naturally metallic, or yielding their oxygen to carbon or to heat alone.

Subdivision 1.

Malleable metals.

GOLD,
PLATINA,
PALLADIUM,
SILVER,[†]
MERCURY,[‡]
TIN.
COPPER,
IRON,
LEAD,
NICKEL,
ZINC,
CADMIUM.[§]

Subdiv. 2.

Brittle metals.

ARSENIC,
BISMUTH,
TELLURIUM,
COBALT,
TUNGSTEN,
MOLYBDENUM,
TITANIUM,
CHROME,
ANTIMONY,
MANGANESE,
URANIUM,
COLUMBIUM *or* **TANTALIUM,**
IRIDIUM,
OSMIUM,
RHODIUM,
CERIUN.[‖]

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[*] Of all these earths, three or four only have as yet been distinctly decomposed.

[†] These first four metals have commonly been distinguished by the appellation of *perfect* or *noble* metals, on account of their possessing the characteristic properties of ductility, malleability, inalterability, and great specific gravity, in an eminent degree.

[‡] Mercury, in its liquid state, cannot, of course, be called a malleable metal. But when frozen, it possesses a considerable degree of malleability.

[§] A metal resembling tin; which was discovered in 1817, in an ore of zinc, by Mr. Stromeyer.

[‖] These last four or five metallic bodies are placed under this class for the sake of arrangement, though some of their properties have not been yet fully investigated.

Caroline. Oh, what a formidable list! you will have much to do to explain it, Mrs. B.; for I assure you it is perfectly unintelligible to me, and I think rather perplexes than assists me.

Mrs. B. Do not let that alarm you, my dear; I hope that hereafter this classification will appear quite clear, and, so far from perplexing you, will assist you in arranging your ideas. It would be in vain to attempt forming a division that would appear perfectly clear to a beginner; for you may easily conceive that a chemical division being necessarily founded on properties with which you are almost wholly unacquainted, it is impossssible that you should at once be able to understand its meaning or appreciate its utility.

But, before we proceed further, it will be necessary to give you some idea of chemical attraction, a power on which the whole science depends.

Chemical Attraction, or the *Attraction of Composition*, consists in the peculiar tendency which bodies of a different nature have to unite with each other. It is by this force that all the compositions, and decompositions, are effected.

Emily. What is the difference between chemical attraction, and the attraction of cohesion, or of aggregation, which you often mentioned to us, in former conversations?

Mrs. B. The attraction of cohesion exists only between particles of the *same* nature, whether simple or compound; thus it unites the particles of a piece of metal which is a simple substance, and likewise the particles of a loaf of bread which is a compound. The attraction of composition, on the contrary, unites and maintains, in a state of combination, particles of a *dissimilar* nature; it is this power that forms each of the compound particles of which bread consists; and it is by the attraction of cohesion that all these particles are connected into a single mass.

Emily. The attraction of cohesion, then, is the power which unites the integrant particles of a body: the attraction of composition that which combines the constituent particles. Is it not so?

Mrs. B. Precisely: and observe that the attraction of cohesion unites particles of a similar nature, without changing their original properties; the result of such an union, therefore, is a body of the same kind as the particles of which it is formed; whilst the attraction of composition, by combining particles of a dissimilar nature, produces compound bodies, quite different from any of their constituents. If for instance, I pour on the piece of copper, contained in this glass, some of this liquid (which is called nitric acid,) for which it has a strong attraction, every particle of the copper will combine with a particle of acid, and together they will form a new body, totally different from either the copper or the acid.

Do you observe the internal commotion that already begins to take place? It is produced by the combination of these two substances,* and yet the acid has in this case to overcome not only the resistance which the strong cohesion of the particles of copper opposes to their combination with it, but also to overcome the weight of the copper, which makes it sink to the bottom of the glass, and prevents the acid from having such free access to it as it would if the metal were suspended in the liquid.

Emily. The acid seems, however, to overcome both these obstacles without difficulty, and appears to be very rapidly dissolving the copper.

Mrs. B. By this means it reduces the copper into more minute parts than could possibly be done by any mechanical power. But as the acid can act only on the surface of the metal, it will be some time before the union of these two bodies will be completed.

You may, however, already see how totally different this compound is from either of its ingredients. It is neither colourless, like the acid, nor hard, heavy, and yellow like the copper. If you tasted it, you would no longer perceive the sourness of the acid. It has at present the appearance of a blue liquid; but when the union is completed, and the water with which the acid is diluted is evaporated, the compound will assume the form of regular crystals of a fine blue colour, and perfectly transparent.† Of these I can show you a specimen, as I have prepared some for that purpose.

Caroline. How beautiful they are, in colour, form, and transparency!

Emily. Nothing can be more striking than this example of chemical attraction.

Mrs. B. The term *attraction* has been lately introduced into chemistry as a substitute for the word *affinity*, to which some chemists have objected, because it originated in the vague notion that chemical combinations depended upon a certain resemblance, or relationship, between particles that are disposed to unite; and this idea is not only imperfect, but erroneous, as it is generally particles of the most dissimilar nature, that have the greatest tendency to combine.

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* This hardly explains the process. A part of the oxygen of the nitric acid unites with the copper; and in consequence of this loss of oxygen, the nitric acid is converted into *nitrous gas*. It is the escape of this gas through the water as it is formed that occasions the commotion. C.

† These crystals are more easily obtained from a mixture of sulphuric with a little nitric acid.‡

‡ These crystals are *sulphate* of *copper*, or what is commonly known under the name of *blue vitriol*. C.

Caroline. Besides, there seems to be no advantage in using a variety of terms to express the same meaning; on the contrary it creates confusion; and as we are well acquainted with the term Attraction in natural philosophy, we had better adopt it in chemistry likewise.

Mrs. B. If you have a clear idea of the meaning, I shall leave you at liberty to express it in the terms you prefer. For myself, I confess that I think the word Attraction best suited to the general law that unites the integrant particles of bodies; and Affinity better adapted to that which combines the constituent particles, as it may convey an idea of the preference which some bodies have for others, which the term *attraction of composition* does not so well express.

Emily. So I think; for though that preference may not result from any relationship, or similitude, between the particles (as you say was once supposed,) yet, as it really exists, it ought to be expressed.

Mrs. B. Well, let it be agreed that you may use the terms *affinity*, *chemical attraction*, and *attraction of composition*, indifferently, provided you recollect that they have all the same meaning.

Emily. I do not conceive how bodies can be decomposed by chemical attraction. That this power should be the means of composing them, is very obvious; but that it should, at the same time, produce exactly the contrary effect, appears to me very singular.

Mrs. B. To decompose a body is, you know, to separate its constituent parts, which, as we have just observed, cannot be done by mechanical means.

Emily. No: because mechanical means separate only the integrant particles; they act merely against the attraction of cohesion, and only divide a compound into smaller parts.

Mrs. B. The decomposition of a body is performed by chemical powers. If you present to a body composed of two principles, a third, which has a greater affinity for one of them than the two first have for each other, it will be decomposed, that is, its two principles will be separated by means of the third body. Let us call two ingredients, of which the body is composed, A and B. If we present to it another ingredient

C, which has a greater affinity for B than that which unites A and B, it necessarily follows that B will quit A to combine with C. The new ingredient, therefore, has effected a decomposition of the original body A B; A has been left alone, and a new compound, B C, has been formed.

Emily. We might, I think, use the comparison of two friends, who were very happy in each other's society, till a third disunited them by the preference which one of them gave to the new-comer.

Mrs. B. Very well. I shall now show you how this takes place in chemistry.

Let us suppose that we wish to decompose the compound we have just formed by the combination of the two ingredients, copper and nitric acid; we may do this by presenting to it a piece of iron, for which the acid has a stronger attraction than for copper; the acid will, consequently quit the copper to combine with the iron, and the copper will be what the chemists call *precipitated*, that is to say, it will be thrown down in its separate state, and re-appear in its simple form.

In order to produce this effect, I shall dip the blade of this knife into the fluid, and, when I take it out, you will observe, that, instead of being wetted with a bluish liquid, like that contained in the glass, it will be covered with a thin coat of copper.

Caroline. So it is really! but then is it not the copper, instead of the acid, that has combined with the iron blade?

Mrs. B. No; you are deceived by appearances: it is the acid which combines with the iron, and, in so doing, deposits or precipitates the copper on the surface of the blade.

Emily. But, cannot three or more substances combine together, without any of them being precipitated?

Mrs. B. That is sometimes the case; but, in general, the stronger affinity destroys the weaker; and it seldom happens that the attraction of several substances for each other is so equally balanced as to produce such complicated compounds.*

Caroline. But, pray, Mrs. B., what is the cause of the chemical attraction of bodies for each other? It appears to me more extraordinary or unnatural, if I may use the expression, than the attraction of cohesion, which unites particles of a similar nature.

Mrs. B. Chemical attraction may, like that of cohesion or gravitation, be one of the powers inherent in matter, which, in our present state of knowledge, admits of no other satisfactory explanation than an immediate reference to a divine cause. Sir H. Davy, however, whose important discoveries have opened such improved views in chemistry, has suggested an hypothesis which may throw great light upon that science. He supposes that there are two kinds of electricity, with one or other of which all bodies are united. These we distinguish by the names of *positive* and *negative* electricity; those bodies are disposed to combine, which possess opposite electricities, as they are brought together by the attraction which these electricities have for each other. But, whether this hypothesis be altogether founded on truth or not, it is impossible to question the great influence of electricity in chemical combinations.

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* Such compounds are quite numerous. They are called *triple* salts. Alum is one. It is composed of Alumine, potash, and sulphuric acid. Tartar Emetic is another. It is composed of tartaric acid, potash and antimony. C.

Emily. So, that we must suppose that the two electricities always attract each other, and thus compel the bodies in which they exist to combine?*

Caroline. And may not this be also the cause of the attraction of cohesion?

Mrs. B. No, for in particles of the same nature the same electricities must prevail, and it is only the different or opposite electric fluids that attract each other.

Caroline. These electricities seem to me to be a kind of chemical spirit, which animates the particles of bodies, and draws them together.

Emily. If it is known, then, with which of the electricities bodies are united, it can be inferred which will, and which will not, combine together?

Mrs. B. Certainly.—I should not omit to mention, that some doubts have been entertained, whether electricity be really a material agent, or whether it might not be a power inherent in bodies, similar to, or perhaps identical with, attraction.

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* There seems to be an objection to this theory as explained here. When two bodies, one in the positive, the other in the negative state of electricity are presented to each other, a mutual attraction takes place, until they touch, or come within the striking distance, so that the electric fluid can pass from the positive to the negative body. When this is effected, they are said to be in a state of equilibrium, or in the same state of electricity, and consequently neither attract nor repel each other. If therefore, chemical attraction depends on the different electrical states of the particles, we are still at a loss how to account for their adhesion even after they are united. The celebrated Kepler accounted for the affinity of particles by supposing each to have its likings and its antipathies, and the power of choosing accordingly. This theory only wants our belief to make it satisfactory. C.

Emily. But what then would be the electric spark which is visible, and, must therefore be really material?

Mrs. B. What we call the electric spark, may, Sir H. Davy says, be merely the heat and light, or fire produced by the chemical combinations with which these phenomena are always connected. We will not, however, enter more fully on this important subject at present, but reserve the principal facts which relate to it to a future conversation.

Before we part, however, I must recommend you to fix in your memory the names of the simple bodies against our next interview.

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CONVERSATION II.

ON LIGHT AND HEAT, OR CALORIC.

Caroline. We have learned by heart the names of all the simple bodies which you have enumerated, and we are now ready to enter on the examination of each of them successively. You will begin, I suppose, with LIGHT?

Mrs. B. Respecting the nature of light we have little more than conjectures. It is considered by most philosophers as a real substance immediately emanating from the sun, and from all luminous bodies, from which it is projected in right lines with prodigious velocity. Light, however, being imponderable, it cannot be confined and examined by itself; and therefore it is to the effects it produces on other bodies, rather than to its immediate nature, that we must direct our attention.

The connection between light and heat is very obvious; indeed, it is such, that it is extremely difficult to examine the one independently of the other.

Emily. But, is it possible to separate light from heat; I thought they were only different degrees of the same thing, fire?

Mrs. B. I told you that fire was not now considered as a simple element. Whether light and heat be altogether different agents, or not, I cannot pretend to decide; but, in many cases, light may be separated from heat. The first discovery of this was made by a celebrated Swedish chemist, Scheele. Another very striking illustration of the separation of heat and light was long after pointed out by Dr. Herschell. This philosopher discovered that these two agents were emitted in the rays of the sun, and that heat was less refrangible than light; for, in separating the different coloured rays of light by a prism (as we did some time ago,) he found that the greatest heat was beyond the spectrum, at a little distance from the red rays, which, you may recollect are the least refrangible.

Emily. I should like to try that experiment.

Mrs. B. It is by no means an easy one: the heat of a ray of light, refracted by a prism, is so small, that it requires a very delicate thermometer to distinguish the difference of the degree of heat within and without the spectrum. For in this experiment the heat is not totally separated from the light, each coloured ray retaining a certain portion of it, though the greatest part is not sufficiently refracted to fall within the spectrum.

Emily. I suppose, then, that those coloured rays which are the least refrangible, retain the greatest quantity of heat?

Mrs. B. They do so.

Emily. Though I no longer doubt that light and heat can be separated, Dr. Herschell's experiment does not appear to me to afford sufficient proof that they are essentially different; for light, which you call a simple body, may likewise be divided into the various coloured rays.

Mrs. B. No doubt there must be some difference in the various coloured rays. Even their chemical powers are different. The blue rays, for instance, have the greatest effect in separating ~~oxygen from bodies, as was found~~ by Scheele; and there exist also, as Dr. Wollaston has shown, rays more refrangible than the blue, which produce the same chemical effect, and, what is very remarkable, are invisible.*

Emily. Do you think it possible that heat may be merely a modification of light?

Mrs. B. That is a supposition which, in the present state of natural philosophy, can neither be positively affirmed nor denied. Let us, therefore, instead of discussing theoretical points, be contented with examining what is known respecting the chemical effects of light.

Light is capable of entering into a kind of transitory union with certain substances, and this is what has been called phosphorescence. Bodies that are possessed of this property, after being exposed to the sun's rays, appear luminous in the dark. The shells of fish, the bones of land animals, marble, limestone, and a variety of combinations of earths, are more or less powerfully phosphorescent.

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* The violet rays have the power of imparting the *magnetic* virtue to steel. The process consists in intercepting all the rays except this, and of throwing this, being first collected into a focus by a lens, on the middle of a needle, and carrying it towards the extremity. This is to be done many times, and always towards the same extremity. After a while the needle acquires polarity. C.

Caroline. I remember being much surprised last summer with the phosphorescent appearance of some pieces of rotten wood, which had just been dug out of the ground; they shone so bright that I at first supposed them to be glow-worms.

Emily. And is not the light of a glow-worm of a phosphorescent nature?

Mrs. B. It is a very remarkable instance of phosphorescence in living animals; this property, however, is not exclusively possessed by the glow-worm. The insect called the lanthorn-fly, which is peculiar to warm climates, emits light as it flies, producing in the dark a remarkably sparkling appearance. But it is more common to see animal matter in a dead state possessed of a phosphorescent quality; sea-fish is often eminently so.*

Emily. I have heard that the sea has sometimes had the appearance of being illuminated, and that the light is supposed to proceed from the spawn of fishes floating on its surface.

Mrs. B. This light is probably owing to that or some other animal matter. Sea water has been observed to become luminous from the substance of a fresh herring having been immersed in it; and certain insects, of the Medusa kind, are known to produce similar effects.

But the strongest phosphorescence is produced by chemical compositions prepared for the purpose, the most common of which consists of oyster-shells and sulphur, and is known by the name of Canton's Phosphorus.†

Emily. I am rather surprised, Mrs. B., that you should have said so much of the light emitted by phosphorescent bodies without taking any notice of that which is produced by burning bodies.

Mrs. B. The light emitted by the latter is so intimately connected with the chemical history of combustion, that I must defer all explanation of it till we come to the examination of that process, which is one of the most interesting in chemical science.

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* The phosphorescence of dead animals is owing to the escape of phosphorus in the form of *phosphoretted hydrogen.* This is set free from its combination with the substance of the animal by the putrefactive fermentation. C.

† To prepare this, mix 3 parts of oyster shells calcined for an hour and pulverized with 1 part of sulphur. This is to be rammed into a crucible, which is to be kept at a red heat for one hour. On exposing some of this to the sun's rays, it absorbs light, and will shine in the dark. This shows that light can be separated from heat. C.

Light is an agent capable of producing various chemical changes. It is essential to the welfare both of the animal and vegetable kingdoms; for men and plants grow pale and sickly if deprived of its salutary influence. It is likewise remarkable for its property of destroying colour, which renders it of great consequence in the process of bleaching.

Emily. Is it not singular that light, which in studying optics we were taught to consider as the source and origin of colours, should have also the power of destroying them?

Caroline. It is a fact, however, that we every day experience; you know how it fades the colours of linens and silks.

Emily. Certainly. And I recollect that endive is made to grow white instead of green, by being covered up so as to exclude the light. But by what means does light produce these effects?

Mrs. B. This I cannot attempt to explain to you until you have obtained a further knowledge of chemistry. As the chemical properties of light can be accounted for only in their reference to compound bodies, it would be useless to detain you any longer on this subject; we may therefore pass on to the examination of heat, or caloric, with which we are somewhat better acquainted.

HEAT and LIGHT may be always distinguished by the different sensations they produce. *Light* affects the sense of sight; *Caloric* that of feeling; the one produces *Vision*, the other the sensation of *Heat*.

Caloric is found to exist in a variety of forms or modifications, and I think it will be best to consider it under the two following heads, viz.

1. FREE OR RADIANT CALORIC.
2. COMBINED CALORIC.

The first, FREE OR RADIANT CALORIC, is also called HEAT OF TEMPERATURE; it comprehends all heat which is perceptible to the senses, and affects the thermometer.

Emily. You mean such as the heat of the sun, of fire, of candles, of stoves; in short, of every thing that burns?

Mrs. B. And likewise of things that do not burn, as, for instance, the warmth of the body; in a word, all heat that is *sensible*, whatever may be its degree, or the source from which it is derived.

Caroline. What then are the other modifications of caloric? It must be a strange kind of heat that cannot be perceived by our senses.

Mrs. B. None of the modifications of caloric should properly be called *heat;* for heat, strictly speaking, is the sensation produced by caloric, on animated bodies; this word, therefore, in the accurate language of science, should be confined to express the sensation. But custom has adapted it likewise, to inanimate matter, and we say *the heat of an oven, the heat of the sun,* without any reference to the sensation which they are capable of exciting.

It was in order to avoid the confusion, which arose from thus confounding the cause and effect, that modern chemists adopted the new word *caloric,* to denote the principle which produces heat; yet they do not always, in compliance with their own language, limit the word *heat* to the expression of the sensation, since they still frequently employ it in reference to the other modifications of caloric which are quite independent of sensation. *

Caroline. But you have not yet explained to us what these other modifications of caloric are.

Mrs. B. Because you are not acquainted with the properties of free caloric, and you know that we have agreed to proceed with regularity.

One of the most remarkable properties of free caloric is its power of *dilating* bodies. This fluid is so extremely subtle, that it enters and pervades all bodies whatever, forces itself between their particles, and not only separates them, but frequently drives them asunder to a considerable distance from each other. It is thus that caloric dilates or expands a body so as to make it occupy a greater space than it did before.

Emily. The effect it has on bodies, therefore, is directly contrary to that of the attraction of cohesion; the one draws the particles together, the other drives them asunder.

Mrs. B. Precisely. There is a continual struggle between the attraction of aggregation, and the expansive power of caloric; and from the action of these two opposite forces, result all the various forms of matter, or degrees of consistence, from the solid to the liquid and aëriform state. And accordingly we find that most bodies are capable of passing from one of these forms to the other, merely in consequence of their receiving different quantities of caloric.

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* If I touch a body at a higher temperature than my hand, I immediately receive a quantity of caloric from it, and at the same instant feel the sensation called heat. The caloric then is the cause of this sensation, and heat the effect of caloric passing into my hand. C.

Caroline. That is very curious; but I think I understand the reason of it. If a great quantity of caloric is added to a solid body, it introduces itself between the particles in such a manner as to overcome, in a considerable degree, the attraction of cohesion; and the body, from a solid, is then converted into a fluid.

Mrs. B. This is the case whenever a body is fused or melted; but if you add caloric to a liquid, can you tell me what is the consequence?

Caroline. The caloric forces itself in greater abundance between the particles of the fluid, and drives them to such a distance from each other, that their attraction of aggregation is wholly destroyed: the liquid is then transformed into vapour.

Mrs. B. Very well; and this is precisely the case with boiling water, when it is converted into steam or vapour, and with all bodies that assume an aëriform state.

Emily. I do not well understand the word aëriform?

Mrs. B. Any elastic fluid whatever; whether it be merely vapour or permanent air, is called aëriform.

But each of these various states, solid, liquid, and aëriform, admit of many different degrees of density, or consistence, still arising (chiefly at least) from the different quantities of caloric the bodies contain. Solids are of various degrees of density, from that of gold, to that of a thin jelly. Liquids, from the consistence of melted glue, or melted metals, to that of ether, which is the lightest of all liquids. The different elastic fluids (with which you are not yet acquainted) are susceptible of no less variety in their degrees of density.

Emily. But does not every individual body also admit of different degress of consistence, without changing its state?

Mrs. B. Undoubtedly; and this I can immediately show you by a very simple experiment. This piece of iron now exactly fits the frame, or ring, made to receive it; but if heated red hot, it will no longer do so, for its dimensions will be so much increased by the caloric that has penetrated into it, that it will be much too large for the frame.

The iron is now red hot; by applying it to the frame, we shall see how much it is dilated.

Emily. Considerably so indeed! I knew that heat had this effect on bodies, but I did not imagine that it could be made so conspicuous.

Mrs. B. By means of this instrument (called a Pyrometer) we may estimate, in the most exact manner, the various dilatations of any solid body by heat. The body we are now going to submit to trial is this small iron bar; I fix it to this apparatus, (Plate I. Fig. 1.) and then heat it by lighting the three lamps beneath it: when the bar expands, it increases in length as well as thickness; and, as one end communicates with this wheel-work, whilst the other end is fixed and immoveable, no sooner does it begin to dilate than it presses against the wheel-work, and sets in motion the index, which points out the degrees of dilatation on the dial-plate.

Emily. This is, indeed, a very curious instrument; but I do not understand the use of the wheels: would it not be more simple, and answer the purpose equally well, if the bar in dilating, pressed against the index, and put it in motion without the intervention of the wheels?

Mrs. B. The use of the wheels is merely to multiply the motion, and therefore render the effect of the caloric more obvious; for if the index moved no more than the bar increased in length, its motion would scarcely be perceptible; but by means of the wheels it moves in a much greater proportion, which therefore renders the variations far more conspicuous.

By submitting different bodies to the test of the pyrometer, it is found that they are far from dilating in the same proportion. Different metals expand in different degrees, and other kinds of solid bodies vary still more in this respect. But this different susceptibility of dilation is still more remarkable in fluids than in solid bodies, as I shall show you. I have here two glass tubes, terminated at one end by large bulbs. We shall fill the bulbs, the one with spirit of wine, the other with water. I have coloured both liquids, in order that the effect may be more conspicuous. The spirit of wine, you see, dilates by the warmth of my hand as I hold the bulb.*

Emily. It certainly does, for I see it is rising into the tube. But water, it seems, is not so easily affected by heat; for scarcely any change is produced on it by the warmth of the hand.

Mrs. B. True; we shall now plunge the bulbs into hot water, (Plate I. Fig. 2.) and you will see both liquids rise in the tubes; but the spirit of wine will ascend highest.

Caroline. How rapidly it expands! Now it has nearly reached the top of the tube, though the water has hardly begun to rise.

Emily. The water now begins to dilate. Are not these glass tubes, with liquids rising within them, very like thermometers?

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* In the absence of glass tubes terminated by bulbs, procure a pair of tin cannisters, 3 inches high and 2 wide, soldered up all round. In the middle of the top of each, have inserted a circular tin spout, and into these cement glass tubes about 12 inches high. These will answer every purpose. C.

PLATE. I.

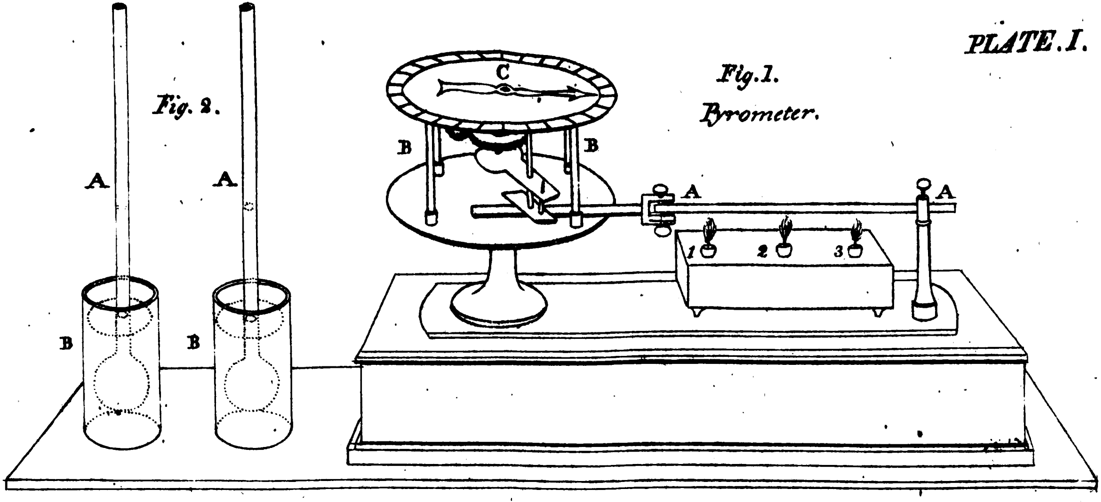
Fig. 2.

Fig. 1.
Pyrometer.

Fig. 1. AA. *Bar of Metal.* 1. 2. 3. *Lamps burning.* B.B. *Wheel work.* C. *Index.* *Fig. 2.* A.A. *Glass tubes with bulbs.* B.B. *Glasses of water in which they are immersed.*

Mrs. B. A thermometer is constructed exactly on the same principle, and these tubes require only a scale to answer the purpose of thermometers: but they would be rather awkward in their dimensions. The tubes and bulbs of thermometers, though of various sizes, are in general much smaller than these; the tube too is hermetically* closed, and the air excluded from it. The fluid most generally used in thermometers is mercury, commonly called quicksilver, the dilatations and contractions of which correspond more exactly to the additions, and subtractions, of caloric, than those of any other fluid.

Caroline. Yet I have often seen coloured spirit of wine used in thermometers.

Mrs. B. The expansions and contractions of that liquid are not quite so uniform as those of mercury; but in cases in which it is not requisite to ascertain the temperature with great precision, spirit of wine will answer the purpose equally well, and indeed in some respects better, as the expansion of the latter is greater, and therefore more conspicuous. This fluid is used likewise in situations and experiments in which mercury would be frozen; for mercury becomes a solid body, like a piece of lead or any other metal, at a certain degree of cold; but no degree of cold has ever been known to freeze spirit of wine.†

A thermometer, therefore, consists of a tube with a bulb, such as you see here, containing a fluid whose degrees of dilatation and contraction are indicated by a scale to which the tube is fixed. The degree which indicates the boiling point, simply means that, when the fluid is sufficiently dilated to rise to this point, the heat is such that water exposed to the same temperature will boil. When, on the other hand, the fluid is so much condensed as to sink to the freezing point, we know that water will freeze at that temperature. The extreme points of the scales are not the same in all thermometers, nor are the degrees always divided in the same manner. In different countries philosophers have chosen to adopt different scales and divisions. The two thermometers most used are those of Fahrenheit, and of Reaumur; the first is generally preferred by the English, the latter by the French.

Emily. The variety of scale must be very inconvenient, and

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* The tube is closed by holding the end over a spirit lamp until the glass is melted. This word is derived from *Hermes*, the Greek name for Mercury. He is said to have been the inventer of chemistry; hence this is sometimes called the *Hermetic art*, and hermetically, or chemically closed, is closed by heat or melting. C.

† Spirit of wine is stated to have been frozen in England by some process which the author has preferred to keep secret. C.

I should think liable to occasion confusion, when French and English experiments are compared.

Mrs. B. The inconvenience is but very trifling, because the different gradations of the scales do not affect the principle upon which thermometers are constructed. When we know, for instance, that Fahrenheit's scale is divided into 212 degrees, in which 32° corresponds with the freezing point, and 212° with the point of boiling water; and that Reaumur's is divided only into 80 degrees, in which 0° denotes the freezing point, and 80° that of boiling water, it is easy to compare the two scales together. and reduce the one into the other. But, for greater convenience, thermometers are sometimes constructed with both these scales, one on either side of the tube; so that the correspondence of the different degrees of the two scales is thus instantly seen. Here is one of these scales, (PLATE II. Fig. 1.) by which you can at once perceive that each degree of Reaumur's corresponds to 2 1-4 of Fahrenheit's division. But I believe the French have, of late, given the preference to what they call the centigrade scale, in which the space between the freezing and the boiling point is divided into 100 degrees.

Caroline. That seems to me the most reasonable division, and I cannot guess why the freezing point is called 32°, or what advantage is derived from it.

Mrs. B. There really is no advantage in it; and it originated in a mistaken opinion of the instrument-maker, Fahrenheit, who first constructed these thermometers. He mixed snow and salt together, and produced by that means a degree of cold which he concluded was the greatest possible, and therefore made his scale begin from that point. Between that and boiling water he made 212 degrees, and the freezing point was found to be at 32°.

Emily. Are spirit of wine, and mercury, the only liquids used in the construction of thermometers?

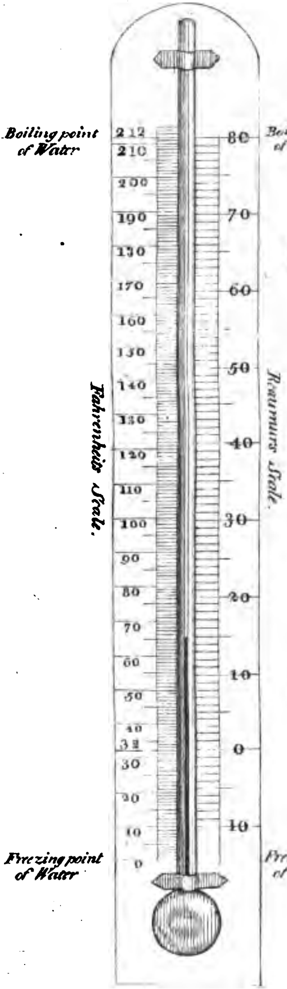
Mrs. B. I believe they are the only liquids now in use, though some others, such as linseed oil, would make tolerable thermometers: but for experiments in which a very quick and delicate test of the changes of temperature is required, air is the fluid sometimes employed. The bulb of air thermometers is filled with common air only, and its expansion and contraction are indicated by a small drop of any coloured liquor, which is suspended within the tube, and moves up and down, according as the air within the bulb and tube expands or contracts. But in general, air thermometers, however sensible to changes of temperature, are by no means accurate in their indications.

I can, however, show you an air thermometer of a very pe-

PLATE II.

THERMOMETER.

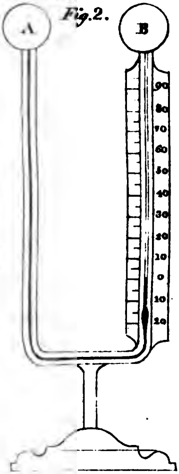
Fig. 1.



Boiling point of Water

Freezing point of Water

Differential Thermometer. Fig.2.



culiar construction, which is remarkably well adapted for some chemical experiments, as it is equally delicate and accurate in its indications. *

Caroline. It looks like a double thermometer reversed, the tube being bent, and having a large bulb at each of its extremities. (PLATE II. Fig. 2.)

Emily. Why do you call it an air thermometer; the tube contains a coloured liquid?

Mrs. B. But observe that the bulbs are filled with air, the liquid being confined to a portion of the tube, and answering only the purpose of showing, by its motion in the tube, the comparative dilatation or contraction of the air within the bulbs, which afford an indication of their relative temperature. Thus if you heat the bulb A, by the warmth of your hand, the fluid will rise towards the bulb B, and the contrary will happen if you reverse the experiment.

But if, on the contrary, both tubes are of the same temperature, as is the case now, the coloured liquid, suffering an equal pressure on each side, no change of level takes place.

Caroline. This instrument appears, indeed, uncommonly delicate. The fluid is set in motion by the mere approach of my hand.

Mrs. B. You must observe, however, that this thermometer cannot indicate the temperature of any particular body, or of the medium in which it is immersed; it serves only to point out the *difference* of temperature between the two bulbs, when placed under different circumstances. For this reason it has been called *differential* thermometer. You will see hereafter to what particular purposes this instrument applies.

Emily. But do common thermometers indicate the exact quantity of caloric contained either in the atmosphere, or in any body with which they are in contact?†

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* Students in chemistry may amuse themselves with air thermometers of their own construction. Procure a flat vial, or inkstand with a wide mouth; also a broken thermometer tube, the bulb being entire. Fit a cork air tight to the vial, and pierce it in the middle with a hot iron to admit the tube Fill the vial about half full of some coloured liquid. Warm the bulb of the tube by holding it in the hand, and in this state introduce the small end through the cork nearly to the bottom of the vial. The hand being removed from the bulb, the fluid will rise in the tube. The fluid will afterwards rise or fall as heat is applied to the vial or bulb. C.

† The thermometer indicates the exact quantity of free caloric present at the time and place of the experiment. Thus if a certain quantity of heat is required to raise the mercury 20°, double this quantity will raise it to 40°. All bodies contain a quantity of heat not appreciable

Mrs. B. No: first, because there are other modifications of caloric which do not affect the thermometer; and, secondly, because the temperature of a body, as indicated by the thermometer, is only relative. When, for instance, the thermometer remains stationary at the freezing point, we know that the atmosphere (or medium in which it is placed, whatever it may be) is as cold as freezing water; and when it stands at the boiling point, we know that this medium is as hot as boiling water; but we do not know the positive quantity of heat contained either in freezing or boiling water, any more than we know the real extremes of heat and cold; and consequently we cannot determine that of the body in which the thermometer is placed.

Caroline. I do not quite understand this explanation.

Mrs. B. Let us compare a thermometer to a well, in which the water rises to different heights, according as it is more or less supplied by the spring which feeds it; if the depth of the well is unfathomable, it must be impossible to know the absolute quantity of water it contains; yet we can with the greatest accuracy measure the number of feet the water has risen or fallen in the well at any time, and consequently know the precise quantiiy of its increase or diminution, without having the least knowledge of the whole quantity of water it contains.*

Caroline. Now I comprehend it very well; nothing appears to me to explain a thing so clearly as a comparison.

Emily. But will thermometers bear any degree of heat?

Mrs. B. No; for if the temperature were much above the highest degree marked on the scale of the thermometer, the mercury would burst the tube in an attempt to ascend. And at any rate, no thermometer can be applied to temperatures higher than the boiling point of the liquid used in its construction, for the steam, on the liquid beginning to boil, would burst the tube. In furnaces, or whenever any very high temperature is to be measured, a pyrometer, invented by Wedgwood, is used for that purpose. It is made of a certain composition of baked

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by the thermometer, or sensible to the touch. This is called *fixed* or *latent* heat. This can sometimes be set free, as when we hammer a piece of cold iron it becomes hot. Thus the latent caloric is squeezed out of the iron by the contraction of its pores under the hammer, and it then becomes *free* caloric. C.

* This passage may be expounded as follows. The unfathomable depth of the well signifies the absolute quantity of caloric, and which the thermometer does not measure; because all bodies however cold, still contain caloric. Thus mercury freezes at 40° below zero, but still contains caloric, and so on. The rising and falling of the water signifies the greater or less quantity of free caloric as indicated by the thermometer. C.

clay, which has the peculiar property of contracting by heat, so that the degree of contraction of this substance indicates the temperature to which it has been exposed.

Emily. But is it possible for a body to contract by heat? I thought that heat dilated all bodies whatever.

Mrs. B. This is not an exception to the rule. You must recollect that the bulk of the clay is not compared, whilst hot, with that which it has when cold; but it is from the change which the clay has undergone by *having been* heated that the indications of this instrument are derived. This change consists in a beginning fusion which tends to unite the particles of clay more closely, thus rendering it less pervious or spongy.*

Clay is to be considered as a spongy body, abounding in interstices or pores, from its having contained water when soft. These interstices are by heat lessened, and would by extreme heat be entirely obliterated.

Caroline. And how do you ascertain the degrees of contraction of Wedgwood's pyrometer?

Mrs. B. The dimensions of the piece of clay are measured by a scale graduated on the side of a tapered groove, formed in a brass ruler; the more the clay is contracted by the heat, the further it will descend into the narrow part of the tube.

Before we quit the subject of expansion, I must observe to you that, as liquids expand more readily than solids, so elastic fluids, whether air or vapour, are the most expansible of all bodies.

It may appear extraordinary that all elastic fluids whatever, undergo the same degree of expansion from equal augmentations of temperature.

Emily. I suppose, then, that all elastic fluids are of the same density?

Mrs. B. Very far from it; they vary in density, more than either liquids or solids. The uniformity of their expansibility, which at first may appear singular, is, however, readily accounted for. For if the different susceptibilities of expansion of bodies arise from their various degrees of attraction of cohesion, no such difference can be expected in elastic fluids, since in these the attraction of cohesion does not exist, their particles being on the contrary possessed of an elastic or repulsive power; they will therefore all be equally expanded by equal degrees of caloric.

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* According to the calculations of Saussure, the temperature necessary to melt this clay is 1575° Wedgwood, which is a degree of heat greatly beyond our common furnaces. It is therefore most probable that the clay contracts at lower temperatures by the loss of moisture. C.

Emily. True; as there is no power opposed to the expansive force of caloric in elastic bodies, its effect must be the same in all of them.

Mrs. B. Let us now proceed to examine the other properties of free caloric.

Free caloric always tends to diffuse itself equally, that is to say, when two bodies are of different temperatures, the warmer gradually parts with its heat to the colder, till they are both brought to the same temperature. Thus, when a thermometer is applied to a hot body, it receives caloric; when to a cold one, it communicates part of its own caloric, and this communication continues until the thermometer and the body arrive at the same temperature.

Emily. Cold, then, is nothing but a negative quality, simply implying the absence of heat.

Mrs. B. Not the total absence, but a diminution of heat; for we know of no body in which some caloric may not be discovered.

Caroline. But when I lay my hand on this marble table, I feel it *positively* cold, and cannot conceive that there is any caloric in it.

Mrs. B. The cold you experience consists in the loss of caloric that your hand sustains in an attempt to bring its temperature to an equilibrium with the marble. If you lay a piece of ice upon it, you will find that the contrary effect will take place; the ice will be melted by the heat it abstracts from the marble.

Caroline. Is it not in this case the air of the room, which being warmer than the marble, melts the ice?

Mrs. B. The air certainly acts on the surface which is exposed to it, but the table melts that part with which it is in contact.

Caroline. But why does caloric tend to an equilibrium? It cannot be on the same principle as other fluids, since it has no weight?

Mrs. B. Very true, Caroline, that is an excellent objection. You might also, with some propriety, object to the term *equilibrium* being applied to a body that is without weight; but I know of no expression that would explain my meaning so well. You must consider it, however, in a figurative rather than a literal sense: its strict meaning is an *equal diffusion.* We cannot, indeed, well say by what power it diffuses itself equally, though it is not surprising that it should go from the parts which have the most to those which have the least. This subject is best explained by a theory suggested by Professor Prevost of Geneva, which is now, I believe, generally adopted.

According to this theory, caloric is composed of particles perfectly separate from each other, every one of which moves with a rapid velocity in a certain direction. These directions vary as much as imagination can conceive, the result of which is, that there are rays or lines of these particles moving with immense velocity in every possible direction. Caloric is thus universally diffused, so that when any portion of space happens to be in the neighbourhood of another, which contains more caloric, the colder portion receives a quantity of calorific rays from the latter, sufficient to restore an equilibrium of temperature. This radiation does not only take place in free space, but extends also to bodies of every kind.* Thus you may suppose all bodies whatever constantly radiating caloric: those that are of the same temperature give out and absorb equal quantities, so that no variation of temperature is produced in them; but when one body contains more free caloric than another, the exchange is always in favour of the colder body, until an equilibrium is effected; this you found to be the case when the marble table cooled your hand, and again when it melted the ice.

Caroline. This reciprocal radiation surprises me extremely; I thought, from what you first said, that the hotter bodies alone emitted rays of caloric which were absorbed by the colder; for it seems unnatural that a hot body should receive any caloric from a cold one, even though it should return a greater quantity.

Mrs. B. It may at first appear so, but it is no more extraordinary than that a candle should send forth rays of light to the sun, which, you know, must necessarily happen.

Caroline. Well, Mrs. B—, I believe that I must give up the point. But I wish I could *see* these rays of caloric; I should then have greater faith in them.

Mrs. B. Will you give no credit to any sense but that of sight? You may feel the rays of caloric which you receive from any body of a temperature higher than your own; the loss of the caloric you part with in return, it is true, is not perceptible; for as you gain more than you lose, instead of suffering a diminution, you are really making an acquisition of caloric. It is, therefore, only when you are parting with it to a body of a lower temperature, that you are sensible of the sensation of cold, because you then sustain an absolute loss of caloric.

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* This is true when applied to inanimate matter. But if a live animal is exposed to a degree of heat above the temperature of its own body, it has the power of resistance; and though the heat be 100 degrees above that of the animal, it scarcely affects its temperature. C.

Emily. And in this case we cannot be sensible of the small quantity of heat we receive in exchange from the colder body, because it serves only to diminish the loss.

Mrs. B. Very well, indeed, Emily. Professor Pictet, of Geneva, has made some very interesting experiments, which prove not only that caloric radiates from all bodies whatever, but that these rays may be reflected, according to the laws of optics, in the same manner as light. I shall repeat these experiments before you, having procured mirrors* fit for the purpose; and it will afford us an opportunity of using the differential thermometer, which is particularly well adapted for these experiments.—I place an iron bullet, (PLATE III. Fig. 1.) about two inches in diameter, and heated to a degree not sufficient to render it luminous, in the focus of this large metallic concave mirror. The rays of heat which fall on this mirror are reflected, agreeably to the property of concave mirrors, in a parallel direction, so as to fall on a similar mirror, which, you see, is placed opposite to the first, at the distance of about ten feet; thence the rays converge to the focus of the second mirror, in which I place one of the bulbs of this thermometer. Now, observe in what manner it is affected by the caloric which is reflected on it from the heated bullet.—The air is dilated in the bulb which we placed in the focus of the mirror, and the liquor rises considerably in the opposite leg.

Emily. But would not the same effect take place, if the rays of caloric from the heated bullet fell directly on the thermometer, without the assistance of the mirrors?

Mrs. B. The effect would in that case be so trifling, at the distance at which the bullet and the thermometer are from each other, that it would be almost imperceptible. The mirrors, you know, greatly increase the effect, by collecting a large quantity of rays into a focus; place your hand in the focus of the mirror, and you will find it much hotter there than when you remove it nearer to the bullet.

Emily. That is very true; it appears extremely singular to

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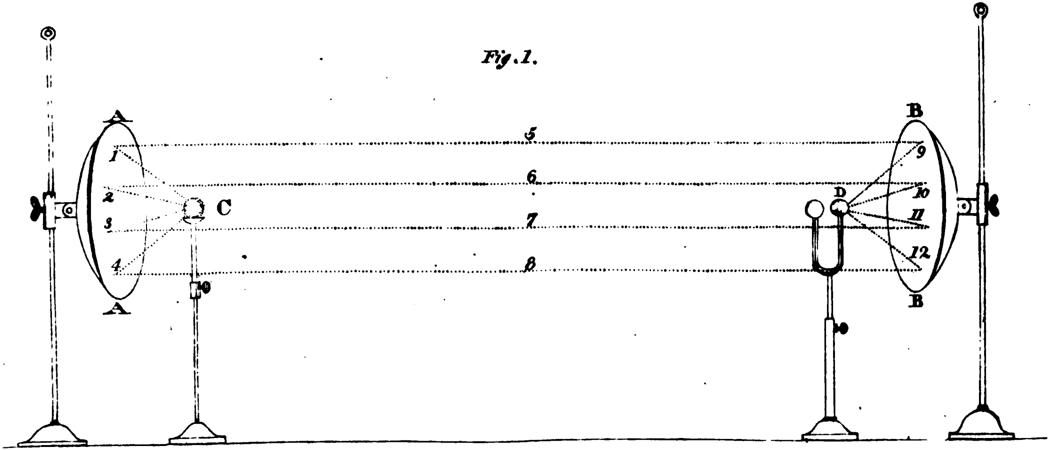
* Mirrors made of common tinned iron show this experiment very well. They may be 10 or 12 inches in diameter, and about 2 inches deep. They must be planished with a hammer having a convex face, and afterwards polished with a piece of buckskin, and a little whiting. C.

PLATE III.

Mr. PICTET'S APPARATUS FOR THE REFLECTION OF HEAT.

Fig. 1.



A.A. & B.B. *Concave mirrors fixed on stands.*_C. *Heated Bullet placed in the focus of the mirror* A._ D *Thermometer with its bulb placed in the focus of the mirror* B. 1.2.3.4 *Rays of Caloric radiating from the bullet & falling on the mirror* A._5.6.7.8 *The same rays reflected from the mirror* A *to the mirror* B._9.10.11.12 *The same rays reflected by the mirror* B *to the Thermometer.*

feel the heat diminish in approaching the body from which it proceeds.

Caroline. And the mirror which produces so much heat, by converging the rays, is itself quite cold.

Mrs. B. The same number of rays that are dispersed over the surface of the mirror are collected by it into the focus; but if you consider how large a surface the mirror presents to the rays, and, consequently, how much they are diffused in comparison to what they are at the focus, which is little more than a point, I think you can no longer wonder that the focus should be so much hotter than the mirror.

The principal use of the mirror in this experiment is, to prove that the calorific emanation is reflected in the same manner as light.

Caroline. And the result, I think, is very conclusive.

Mrs. B. The experiment may be repeated with a wax taper instead of the bullet, with a view of separating the light from the caloric. For this purpose a transparent plate of glass must be interposed between the mirrors; for light, you know, passes with great facility through glass, whilst the transmission of caloric is almost wholly impeded by it. We shall find, however, in this experiment, that some few of the calorific rays pass through the glass together with the light, as the thermometer rises a little; but, as soon as the glass is removed, and a free passage left to the caloric, it will rise considerably higher.

Emily. This experiment, as well as that of Dr. Herschell's, proves that light and heat may be separated; for in the latter experiment the separation was not perfect, any more than in that of Mr. Pictet.

Caroline. I should like to repeat this experiment, with the difference of substituting a cold body instead of a hot one, to see whether cold would not be reflected as well as heat.

Mrs. B. That experiment was proposed to Mr. Pictet by an incredulous philosopher like yourself, and he immediately tried it by substituting a piece of ice in the place of the heated bullet.

Caroline. Well, Mrs. B., and what was the result?

Mrs. B. That we shall see; I have procured some ice for the purpose.

Emily. The thermometer falls considerably!

Caroline. And does not that prove that cold is not merely a *negative* quality, implying simply an inferior degree of heat? The cold must be *positive*, since it is capable of reflection.

Mrs. B. So it at first appeared to Mr. Pictet; but upon a little consideration he found that it afforded only an additional proof of the reflection of heat: this I shall endeavour to explain to you.

According to Mr. Prevost's theory, we suppose that all bodies whatever radiate caloric; the thermometer used in these experiments therefore emits calorific rays in the same manner as any other substance. When its temperature is in equilibrium with that of the surrounding bodies, it receives as much caloric as it parts with, and no change of temperature is produced. But when we introduce a body of a lower temperature, such as a piece of ice, which parts with less caloric than it receives, the consequence is, that its temperature is raised, whilst that of the surrounding bodies is proportionally lowered.

Emily. If, for instance, I was to bring a large piece of ice into this room, the ice would in time be melted, by absorbing caloric from the general radiation which is going on throughout the room; and as it would contribute very little caloric in return for what is absorbed, the room would necessarily be cooled by it.

Mrs. B. Just so; and as in consequence of the mirrors, a more considerable exchange of rays takes place between the ice and the thermometer, than between these and any of the surrounding bodies, the temperature of the thermometer must be more lowered than that of any other adjacent object.

Caroline. I confess I do not perfectly understand your explanation.

Mrs. B. This experiment is exactly similar to that made with the heated bullet: for, if we consider the thermometer as the hot body (which it certainly is in comparison to the ice,) you may then easily understand that it is by the loss of the calorific rays which the thermometer sends to the ice, and not by any cold rays received from it, that the fall of the mercury is occasioned: for the ice, far from emitting rays of cold, sends forth rays of caloric, which diminish the loss sustained by the thermometer.

Let us say, for instance, that the radiation of the thermometer towards the ice is equal to 20, and that of the ice towards the thermometer to 10: the exchange in favour of the ice is as 20 is to 10, or the thermometer absolutely loses 10, whilst the ice gains 10.

Caroline. But if the ice actually sends rays of caloric to the thermometer, must not the latter fall still lower when the ice is removed?

Mrs. B. No; for the space which the ice occupied, admits rays from all the surrounding bodies to pass through it; and those being of the same temperature as the thermometer, will not affect it, because as much heat now returns to the thermometer as radiates from it.

Caroline. I must confess that you have explained this in so satisfactory a manner, that I cannot help being convinced now that cold has no real claim to the rank of a positive being.

Mrs. B. Before I conclude the subject of radiation I must observe to you, that different bodies (or rather surfaces) possess the power of radiating caloric in very different degrees.

Some curious experiments have been made by Mr. Leslie on this subject, and it was for this purpose that he invented the differential thermometer; with its assistance he ascertained that black surfaces radiate most, glass next, and polished surfaces the least of all.

Emily. Supposing these surfaces, of course, to be all of the same temperature.

Undoubtedly. I will now show you the very simple and ingenious apparatus, by means of which he made these experiments. This cubical tin vessel, or canister, has each of its sides externally covered with different materials; the one is simply blackened; the next is covered with white paper; the third with a pane of glass, and in the fourth the polished tin surface remains uncovered. We shall fill this vessel with hot water, so that there can be no doubt but that all its sides will be of the same temperature. Now let us place it in the focus of one of the mirrors, making each of its sides front it in succession. We shall begin with the black surface.*

Caroline. It makes the thermometer which is in the focus of the other mirror rise considerably.—Let us turn the paper surface towards the mirror. The thermometer falls a little, therefore of course this side cannot emit or radiate so much caloric as the blackened side.

Emily. This is very surprising; for the sides are exactly of the same size, and must be of the same temperature. But let us try the glass surface.

Mrs. B. The thermometer continues falling, and with the plain surface it falls still lower; these two surfaces therefore radiate less and less.

Caroline. I think I have found out the reason of this.

Mrs. B. I should be very happy to hear it, for it has not yet (to my knowledge) been accounted for.

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*The radiating power of different surfaces may be shown thus. Take a common half pint tin cup, scour one side bright, and paint or smoke the other black. Place this in the focus of the mirror, and the thermometer will rise or fall as its sides are changed. C.

Caroline. The water within the vessel gradually cools, and the thermometer in consequence gradually falls.

Mrs. B. It is true that the water cools, but certainly in much less proportion than the thermometer descends, as you will perceive if you now change the tin surface for the black one.

Caroline. I was mistaken certainly, for the thermometer rises again now that the black surface fronts the mirror.

Mrs. B. And yet the water in the vessel is still cooling, Caroline.

Emily. I am surprised that the tin surface should radiate the least caloric, for a metallic vessel filled with hot water, a silver tea-pot, for instance, feels much hotter to the hand than one of black earthenware.

Mrs. B. That is owing to the different power which various bodies possess for *conducting* caloric, a property which we shall presently examine. Thus, although a metallic vessel feels warmer to the hand, a vessel of this kind is known to preserve the heat of the liquid within, better than one of any other materials; it is for this reason that silver tea-pots make better tea than those of earthen ware.

Emily. According to these experiments, light-coloured dresses, in cold weather, should keep us warmer than black clothes, since the latter radiate so much more than the former.

Mrs. B. And that is actually the case.

Emily. This property, of different surfaces to radiate in different degrees, appears to me to be at variance with the equilibrium of caloric; since it would imply that those bodies which radiate most, must ultimately become coldest.

Suppose that we were to vary this experiment, by using two metallic vessels full of boiling water, the one blackened, the other not; would not the black one cool the first?

Caroline. True; but when they were both brought down to the temperature of the room, the interchange of caloric between the canisters and the other bodies of the room being then equal, their temperatures would remain the same.

Emily. I do not see why that should be the case; for if different surfaces of the same temperature radiate in different degrees when heated, why should they not continue to do so when cooled down to the temperature of the room?

Mrs. B. You have started a difficulty, Emily, which certainly requires explanation. It is found by experiment, that the power of absorption corresponds with and is proportional to that of radiation; so that under equal temperatures, bodies compensate for the greater loss they sustain in consequence of their greater radiation by their greater absorption; so that if you were to make your experiment in an atmosphere heated like the canisters, to the temperature of boiling water, though it is true that the canisters would radiate in different degrees, no change of temperature would be produced in them, because they would each absorb caloric in proportion to their respective radiation.

Emily. But would not the canisters of boiling water also absorb caloric in different degrees in a room of the common temperature?

Mrs. B. Undoubtedly they would. But the various bodies in the room would not, at a lower temperature, furnish either of the canisters with a sufficiency of caloric to compensate for the loss they undergo; for, suppose the black canister to absorb 400 rays of caloric, whilst the metallic one absorbed only 200; yet if the former radiate 800, whilst the latter radiates only 400, the black canister will be the first cooled down to the temperature of the room. But from the moment the equilibrium of temperature has taken place, the black canister, both receiving and giving out 400 rays, and the metallic one 200, no change of temperature will take place.

Emily. I now understand it extremely well. But what becomes of the surplus of calorific rays, which good radiators emit and bad radiators refuse to receive: they must wander about in search of a resting-place?

Mrs. B. They really do so; for they are rejected and sent back, or, in other words, *reflected* by the bodies which are bad radiators of caloric; and they are thus transmitted to other bodies which happen to lie in their way, by which they are either absorbed or again reflected, according as the property of reflection, or that of absorption, predominates in these bodies.

Caroline. I do not well understand the difference between radiating and reflecting caloric, for the caloric that is reflected from a body proceeds from it in straight lines, and may surely be said to radiate from it?

Mrs. B. It is true that there at first appears to be a great analogy between *radiation* and *reflection*, as they equally convey the idea of the transmission of caloric.

But if you consider a little, you will perceive that when a body *radiates* caloric, the heat which it emits not only proceeds from, but has its origin in the body itself. Whilst when a body *reflects* caloric, it parts with none of its own caloric, but only reflects that which it receives from other bodies.

Emily. Of this difference we have very striking examples before us, in the tin vessel of water, and the concave mirrors;

the first radiates its own heat, the latter reflect the heat which they receive from other bodies.

Caroline. Now, that I understand the difference, it no longer surprises me that bodies which radiate, or part with their own caloric freely, should not have the power of transmitting with equal facility that which they receive from other bodies.

Emily. Yet no body can be said to possess caloric of its own, if all caloric is originally derived from the sun.

Mrs. B. When I speak of a body radiating its own caloric, I mean that which it has absorbed and incorporated either immediately from the sun's rays, or through the medium of any other substance.

Caroline. It seems natural enough that the power of absorption should be in opposition to that of reflection, for the more caloric a body receives, the less it will reject.

Emily. And equally so that the power of radiation should correspond with that of absorption. It is, in fact, cause and effect; for a body cannot radiate heat without having previously absorbed it; just as a spring that is well fed flows abundantly.

Mrs. B. Fluids are in general very bad radiators of caloric; and air neither radiates nor absorbs caloric in any sensible degree.

We have not yet concluded our observations on free caloric. But I shall defer, till our next meeting, what I have further to say on this subject. I believe it will afford us ample conversation for another interview.

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CONVERSATION III.

CONTINUATION OF THE SUBJECT.

Mrs. B. In our last conversation, we began to examine the tendency of caloric to restore an equilibrium of temperature. This property when once well understood, affords the explanation of a great variety of facts which appeared formerly unaccountable. You must observe, in the first place, that the effect of this tendency is gradually to bring all bodies that are in contact to the same temperature. Thus the fire which burns in the grate, communicates its heat from one object to another, till every part of the room has an equal proportion of it.

Emily. And yet this book is not so cold as the table on which it lies, though both are at an equal distance from the fire, and actually in contact with each other, so that, according to your theory, they should be exactly of the same temperature.

Caroline. And the hearth, which is much nearer the fire than the carpet, is certainly the colder of the two.

Mrs. B. If you ascertain the temperature of these several bodies by a thermometer (which is a much more accurate test than your feeling,) you will find that it is exactly the same.

Caroline. But if they are of the same temperature, why should the one feel colder than the other?

Mrs. B. The hearth and the table feel colder than the carpet or the book, because the latter are not such good *conductors of heat* as the former. Caloric finds a more easy passage through marble and wood, than through leather and worsted; the two former will therefore absorb heat more rapidly from your hand, and consequently give it a stronger sensation of cold than the two latter, although they are all of them really of the same temperature.

Caroline. So, then, the sensation I feel on touching a cold body, is in proportion to the rapidity with which my hand yields its heat to that body?

Mrs. B. Precisely; and if you lay your hand successively on every object in the room, you will discover which are good, and which are bad conductors of heat, by the different degrees of cold which you feel. But in order to ascertain this point, it is necessary that the several substances should be of the same temperature, which will not be the case with those that are very near the fire, or those that are exposed to a current of cold air from a window or door.

Emily. But what is the reason that some bodies are better conductors of heat than others?

Mrs. B. This is a point not well ascertained. It has been conjectured that a certain union or adherence takes place between the caloric and the particles of the body through which it passes. If this adherence be strong, the body detains the heat, and parts with it slowly and reluctantly; if slight, it propagates it freely and rapidly. The conducting power of a body is therefore, inversely, as its tendency to unite with caloric.

Emily. That is to say that the best conductors are those that have the least affinity for caloric.

Mrs. B. Yes; but the term affinity is objectionable in this case, because, as that word is used to express a chemical attraction (which can be destroyed only by decomposition,) it cannot be applicable to the slight and transient union that takes place between free caloric and the bodies through which it passes; an union which is so weak, that it constantly yields to the tendency which caloric has to an equilibrium. Now you clearly understand, that the passage of caloric, through bodies that are good conductors, is much more rapid than through those that are bad conductors, and that the former both give and receive it more quickly, and therefore, in a given time, more abundantly, than bad conductors, which makes them feel either hotter or colder, though they may be, in fact, both of the same temperature.

Caroline. Yes, I understand it now; the table, and the book lying upon it, being really of the same temperature, would each receive, in the same space of time, the same quantity of heat from my hand, were their conducting powers equal; but as the table is the best conductor of the two, it will absorb the heat from my hand more rapidly, and consequently produce a stronger sensation of cold than the book.

Mrs. B. Very well, my dear; and observe, likewise, that if you were to heat the table and the book an equal number of degrees above the temperature of your body, the table, which before felt the colder, would now feel the hotter of the two; for, as in the first case it took the heat most rapidly from your hand, so it will now impart heat most rapidly to it. Thus the marble table, which seems to us colder than the mahogany one, will prove the hotter of the two to the ice; for, if it takes heat more rapidly from our hands, which are warmer, it will give out heat more rapidly to the ice, which is colder. Do you understand the reason of these apparently opposite effects?

Emily. Perfectly. A body which is a good conductor of caloric, affords it a free passage; so that it penetrates through that body more rapidly than through one which is a bad conductor; and consequently, if it is colder than your hand, you lose more caloric, and if it is hotter, you gain more than with a bad conductor of the same temperature.

Mrs. B. But you must observe that this is the case only when the conductors are either hotter or colder than your hand; for, if you heat different conductors to the temperature of your body, they will all feel equally warm, since the exchange of caloric between bodies of the same temperature is equal. Now, can you tell me why flannel clothing, which is a very bad conductor of heat, prevents our feeling cold?

Caroline. It prevents the cold from penetrating . . . .

Mrs. B. But you forget that cold is only a negative quality.

Caroline. True; it only prevents the heat of our bodies from escaping so rapidly as it would otherwise do.

Mrs. B. Now you have explained it right; the flannel rather keeps in the heat, than keeps out the cold. Were the atmosphere of a higher temperature than our bodies, it would be equally efficacious in keeping their temperature at the same degree, as it would prevent the free access of the external heat, by the difficulty with which it conducts it.

Emily. This, I think, is very clear. Heat, whether external or internal, cannot easily penetrate flannel; therefore in cold weather it keeps us warm, and if the weather were hotter than our bodies, it would keep us cool.

Mrs. B. The most dense bodies are, generally speaking, the best conductors of heat; probably because the denser the body the greater are the number of points or particles that come in contact with caloric. At the common temperature of the atmosphere, a piece of metal will feel much colder than a piece of wood, and the latter than a piece of woollen cloth; this again will feel colder than flannel; and down, which is one of the lightest, is at the same time one of the warmest bodies.*

Caroline. This is, I suppose, the reason that the plumage of birds preserve them so effectually from the influence of cold in winter?

Mrs. B. Yes; but though feathers in general are an excellent preservative against cold, down is a kind of plumage peculiar to aquatic birds, and covers their chest, which is the part most exposed to the water; for though the surface of the water is not of a lower temperature than the atmosphere, yet, as it is a better conductor of heat, it feels much colder, consequently the chest of the bird requires a warmer covering, than any other part of its body. Besides, the breasts of aquatic birds are exposed to cold, not only from the temperature of the water, but also from the velocity with which the breast of the bird strikes against it; and likewise from the rapid evaporation occasioned in that part by the air against which it strikes, after it has been moistened by dipping from time to time into the water.

If you hold a finger of one hand motionless in a glass of water, and at the same time move a finger of the other hand swiftly through water of the same temperature, a different sensation will be soon perceived in the different fingers.†

Most animal substances, especially those which Providence has assigned as a covering for animals, such as fur, wool, hair, skin, &c. are bad conductors of heat, and are, on that account, such excellent preservatives against the inclemency of winter, that our warmest apparel is made of these materials.

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* One reason why fur, down, &c. conduct heat so badly, is, that they contain a large quantity of air, which is a worse conductor than the materials themselves. C.

† The reason seems to be, that the finger, when it is still, warms the water in contact with it: while the one that is stirring is constantly exposed to fresh applications of cold. C.

Emily. Wood is, I dare say, not so good a conductor as metal, and it is for that reason, no doubt, that silver tea-pots have always wooden handles.

Mrs. B. Yes; and it is the facility with which metals conduct caloric that made you suppose that a silver pot radiated more caloric than an earthen one. The silver pot is in fact hotter to the hand when in contact with it; but it is because its conducting power more than counterbalances its deficiency in regard to radiation.

We have observed that the most dense bodies are in general the best conductors; and metals, you know, are of that class. Porous bodies, such as the earths and wood, are worse conductors, chiefly, I believe, on account of their pores being filled with air; for air is a remarkably bad conductor.

Caroline. It is a very fortunate circumstance that air should be a bad conductor, as it tends to preserve the heat of the body when exposed to cold weather.

Mrs. B. It is one of the many benevolent dispensations of Providence, in order to soften the inclemency of the seasons, and to render almost all climates habitable to man.

In fluids of different densities, the power of conducting heat varies no less remarkably; if you dip your hand into this vessel full of mercury, you will scarcely conceive that its temperature is not lower than that of the atmosphere.

Caroline. Indeed I know not how to believe it, it feels so extremely cold.—But we may easily ascertain its true temperature by the thermometer.—It is really not colder than the air;—the apparent difference then is produced merely by the difference of the conducting power in mercury and in air.

Mrs. B. Yes; hence you may judge how little the sense of feeling is to be relied on as a test of the temperature of bodies, and how necessary a thermometer is for that purpose.

It has indeed been doubted whether fluids have the power of conducting caloric in the same manner as solid bodies. Count Rumford, a very few years since, attempted to prove, by a variety of experiments, that fluids, when at rest, were not at all endowed with this property.

Caroline. How is that possible, since they are capable of imparting cold or heat to us; for if they did not conduct heat, they would neither take it from, nor give it to us?

Mrs. B. Count Rumford did not mean to say that fluids would not communicate their heat to solid bodies; but only that heat does not pervade fluids, that is to say, is not transmitted from one particle of a fluid to another, in the same manner as in solid bodies.

Emily. But when you heat a vessel of water over the fire, if the particles of water do not communicate heat to each other, how does the water become hot throughout?

Mrs. B. By constant agitation. Water, as you have seen, expands by heat in the same manner as solid bodies; the heated particles of water, therefore, at the bottom of the vessel, become specifically lighter than the rest of the liquid, and consequently ascend to the surface, where, parting with some of their heat to the colder atmosphere, they are condensed, and give way to a fresh succession of heated particles ascending from the bottom, which having thrown off their heat at the surface, are in their turn displaced. Thus every particle is successively heated at the bottom, and cooled at the surface of the liquid; but as the fire communicates heat more rapidly than the atmosphere cools the succession of surfaces, the whole of the liquid in time becomes heated.

Caroline. This accounts most ingeniously for the propagation of heat upwards. But suppose you were to heat the upper surface of a liquid, the particles being specifically lighter than those below, could not descend: how therefore would the heat be communicated downwards?

Mrs. B. If there were no agitation to force the heated surface downwards, Count Rumford assures us that the heat would not descend. In proof of this he succeeded in making the upper surface of a vessel of water boil and evaporate, while a cake of ice remained frozen at the bottom.*

Caroline. That is very extraordinary indeed!

Mrs. B. It appears so, because we are not accustomed to heat liquids by their upper surface; but you will understand this theory better if I show you the internal motion that takes place in liquids when they experience a change of temperature. The motion of the liqnid itself is indeed invisible from the extreme minuteness of its particles; but if you mix with it any coloured dust, or powder, of nearly the same specific gravity as the liquid, you may judge of the internal motion of the latter by that of the coloured dust it contains.—Do you see the small piece of amber moving about in the liquid contained in this phial?

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* Dr. Thomson says—"All fluids, however, are capable of conducting caloric; for when the source of heat is applied to their surface, the caloric gradually makes its way downwards, and the temperature of every stratum gradually diminishes from the surface to the bottom of the liquid." C.

Caroline. Yes, perfectly.

Mrs. B. We shall now immerse the phial in a glass of hot water, and the motion of the liquid will be shown by that which it communicates to the amber.

Emily. I see two currents, the one rising along the sides of the phial, the other descending in the centre; but I do not understand the reason of this.

Mrs. B. The hot water communicates its caloric, through the medium of the phial, to the particles of the fluid nearest to the glass; these dilate and ascend laterally to the surface, where, in parting with their heat, they are condensed, and in descending, form the central current.

Caroline. This is indeed a very clear and satisfactory experiment; but how much slower the currents now move than they did at first?

Mrs. B. It is because the circulation of particles has nearly produced an equilibrium of temperature between the liquid in the glass and that in the phial.

Caroline. But these communicate laterally, and I thought that heat in liquids could be propagated only upwards.

Mrs. B. You do not take notice that the heat is imparted from one liquid to the other, through the medium of the phial itself, the external surface of which receives the heat from the water in the glass, whilst its internal surface transmits it to the liquid it contains. Now take the phial out of the hot water, and observe the effect of its cooling.

Emily. The currents are reversed; the external current now descends, and the internal one rises.—I guess the reason of this change:—the phial being in contact with cold air instead of hot water, the external particles are cooled instead of being heated; they therefore descend and force up the central particles; which, being warmer, are consequently lighter.

Mrs. B. It is just so. Count Rumford hence infers, that no alteration of temperature can take place in a fluid, without an internal motion of its particles; and as this motion is produced only by the comparative levity of the heated particles, heat cannot be propagated downwards.

But though I believe that Count Rumford's theory as to heat being incapable of pervading fluids is not strictly correct, yet there is, no doubt, much truth in his observation, that the communication is materially promoted by a motion of the parts; and this accounts for the cold that is found to prevail at the bottom of the lakes in Switzerland, which are fed by rivers issuing from the snowy Alps. The water of these rivers being colder, and therefore more dense than that of the lakes, subsides to the bottom, where it cannot be affected by the warmer temperature of the surface; the motion of the waves may communicate this temperature to some little depth, but it can descend no further than the agitation extends.

Emily. But when the atmosphere is colder than the lake, the colder surface of the water will descend, for the very reason that the warmer will not.

Mrs. B. Certainly; and it is on this account that neither a lake, nor any body of water whatever, can be frozen until every particle of the water has risen to the surface to give off its caloric to the colder atmosphere; therefore the deeper a body of water is, the longer will be the time it requires to be frozen.

Emily. But if the temperature of the whole body of water be brought down to the freezing point, why is only the surface frozen?

Mrs. B. The temperature of the whole body is lowered, but not to the freezing point. The diminution of heat, as you know, produces a contraction in the bulk of fluids, as well as of solids. This effect, however, does not take place in water below the temperature of 40 degrees, which is 8 degrees above the freezing point. At that temperature, therefore, the internal motion, occasioned by the increased specific gravity of the condensed particles, ceases; for when the water at the surface no longer condenses, it will no longer descend, and leave a fresh surface exposed to the atmosphere: this surface alone, therefore, will be further exposed to its severity, and will soon be brought down to the freezing point, when it becomes ice, which being a bad conductor of heat, preserves the water beneath a long time from being affected by the external cold.

Caroline. And the sea does not freeze, I suppose, because its depth is so great, that a frost never lasts long enough to bring down the temperature of such a great body of water to 40 degrees?

Mrs. B. That is one reason why the sea, as a large mass of water, does not freeze. But, independently of this, salt water does not freeze till it is cooled much below 32 degrees, and with respect to the law of condensation, salt water is an exception, as it condenses even many degrees below the freezing point. When the caloric of fresh water, therefore, is imprisoned by the ice on its surface, the ocean still continues throwing off heat into the atmosphere, which is a most signal dispensation of Providence to moderate the intensity of the cold in winter.

Caroline. This theory of the non-conducting power of liquids, does not, I suppose, hold good with respect to air, otherwise the atmosphere would not be heated by the rays of the sun passing through it?

Mrs. B. Nor is it heated in that way. The pure atmosphere is a perfectly transparent medium, which neither radiates, absorbs, nor conducts caloric, but transmits the rays of the sun to us without in any way diminishing their intensity. The air is therefore not more heated, by the sun's rays passing through it, than diamond, glass, water, or any other transparent medium.*

Caroline. That is very extraordinary! Are glass windows not heated then by the sun shining on them?

Mrs. B. No; not if the glass be perfectly transparent. A most convincing proof that glass transmits the rays of the sun without being heated by them is afforded by the burning lens, which by converging the rays to a focus will set combustible bodies on fire, without its own temperature being raised.

Emily. Yet, Mrs. B., if I hold a piece of glass near the fire, it is almost immediately warmed by it; the glass therefore must retain some of the caloric radiated by the fire? Is it that the solar rays alone pass freely through glass without paying tribute? It seems unaccountable that the radiation of a common fire should have power to do what the sun's rays cannot accomplish.

Mrs. B. It is not because the rays from the fire have more power, but rather because they have less, that they heat glass and other transparent bodies. It is true, however, that as you approach the source of heat the rays being nearer each other, the heat is more condensed, and can produce effects of which the solar rays, from the great distance of their source, are incapable. Thus we should find it impossible to roast a joint of meat by the sun's rays, though it is so easily done by culinary heat. Yet calorie emanated from burning bodies, which is commonly called *culinary heat*, has neither the intensity nor the velocity of solar rays. All caloric, we have said, is supposed to proceed originally from the sun; but after having been incorporated with terrestrial bodies, and again given out by them, though its nature is not essentially altered, it retains neither the intensity nor the velocity with which it first emanated from that luminary; it has therefore not the power of passing through transparent mediums, such as glass and water, without being partially retained by those bodies.

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* To show still better that transparent media are not heated by the rays of the sun, throw the focus of a burning lens into a vessel of clear water. No effect on the temperature will be produced; but if an opake body, as a piece of cork be introduced under the focus, the water at this point instantly begins to boil. C.

Emily. I recollect that in the experiment on the reflection of heat, the glass skreen which you interposed between the burning taper and the mirror, arrested the rays of caloric, and suffered only those of light to pass through it.

Caroline. Glass windows, then, though they cannot be heated by the sun shining on them, may be heated internally by a fire in the room? But, Mrs. B., since the atmosphere is not warmed by the solar rays passing through it, how does it obtain heat; for all the fires that are burning on the surface of the earth would contribute very little towards warming it?

Emily. The radiation of heat is not confined to burning bodies; for all bodies, you know, have that property; therefore not only every thing upon the surface of the earth, but the earth itself, must radiate heat; and this terrestrial caloric, not having, I suppose, sufficient power to traverse the atmosphere, communicates heat to it.

Mrs. B. Your inference is extremely well drawn, Emily; but the foundation on which it rests is not sound: for the fact is, that terrestrial or culinary heat, though it cannot pass through the denser transparent mediums, such as glass or water, without loss, traverses the atmosphere completely; so that all the heat which the earth radiates, unless it meet with clouds* or any foreign body to intercept its passage, passes into the distant regions of the universe.

Caroline. What a pity that so much heat should be wasted!

Mrs. B. Before you are tempted to object to any law of nature, reflect whether it may not prove to be one of the numberless dispensations of Providence for our good. If all the heat which the earth has received from the sun, since the creation had been accumulated in it, its temperature by this time would, no doubt, have been more elevated than any human being could have borne.

Caroline. I spoke indeed very inconsiderately. But, Mrs. B., though the earth, at such a high temperature, might have scorched our feet, we should always have had a cool refreshing air to breathe, since the radiation of the earth does not heat the atmosphere.

Emily. The cool air would have afforded but very insufficient refreshment, whilst our bodies were exposed to the burning radiation of the earth.

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* Every one has observed how oppressive the heat is on a foggy, or cloudy day in the summer. The moisture of the fog absorbs the heat which the earth radiates, and throws it back upon the earth again, and upon us. C.

Mrs. B. Nor should we have breathed a cool air; for though it is true that heat is not communicated to the atmosphere by radiation, yet the air is warmed by contact with heated bodies, in the same manner as solids or liquids. The stratum of air which is immediately in contact with the earth is heated by it; it becomes specifically lighter and rises, making way for another stratum of air which is in its turn heated and carried upwards; and thus each successive stratum of air is warmed by coming in contact with the earth. You may perceive this effect in a sultry day, if you attentively observe the strata of air near the surface of the earth; they appear in constant agitation, for though it is true the air is itself invisible, yet the sun shining on the vapours floating in it, render them visible, like the amber dust in the water. The temperature of the surface of the earth is therefore the source from whence the atmosphere derives its heat, though it is communicated neither by radiation, nor transmitted from one particle of it to another by the conducting power; but every particle of air must come in contact with the earth in order to receive heat from it.

Emily. Wind then by agitating the air should contribute to cool the earth and warm the atmosphere, by bringing a more rapid succession of fresh strata of air in contact with the earth, and yet in general wind feels cooler than still air?

Mrs. B. Because the agitation of the air carries off heat from the surface of our bodies more rapidly than still air, by occasioning a greater number of points of contact in a given time.

Emily. Since it is from the earth and not the sun that the atmosphere receives its heat, I no longer wonder that elevated regions should be colder than plains and valleys; it was always a subject of astonishment to me, that in ascending a mountain and approaching the sun, the air became colder instead of being more heated.

Mrs. B. At the distance of about a hundred million of miles, which we are from the sun, the approach of a few thousand feet makes no sensible difference, whilst it produces a very considerable effect with regard to the warming the atmosphere at the surface of the earth.

Caroline. Yet as the warm air arises from the earth and the cold air descends to it, I should have supposed that heat would have accumulated in the upper regions of the atmosphere, and that we should have felt the air warmer as we ascended?

Mrs. B. The atmosphere, you know, diminishes in density,

PLATE IV.

Fig. 1.

Pneumatic Pump.

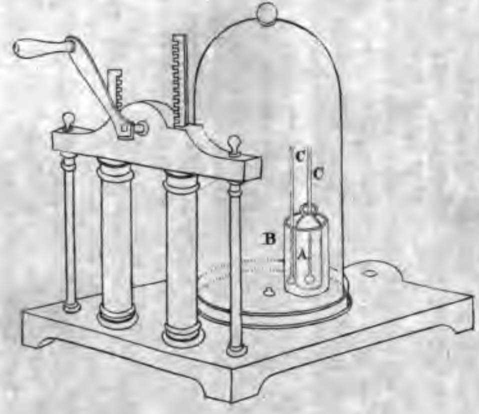

Fig. 2.

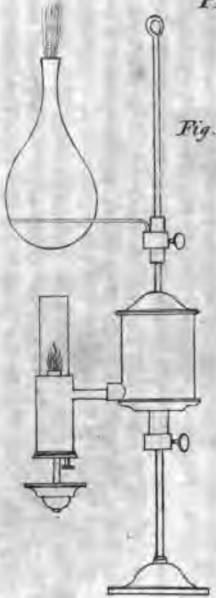

Fig. 2. Boiling water in a flask over a Patent Lamp._ Fig 1. Ether evaporated & water frozen in the air pump._ A Phial of Ether._ B Glass vessel containing water._ CC. Thermometers one in the Ether, the ether in the water.

and consequently in weight, as it is more distant from the earth; the warm air, therefore, rises till it meets with a stratum of air of its own density; and it will not ascend into the upper regions of the atmosphere until all the parts beneath have been previously heated. The length of summer even in warm climates does not heat the air sufficiently to melt the snow which has accumulated during the winter on very high mountains, although they are almost constantly exposed to the heat of the sun's rays, being too much elevated to be often enveloped in clouds.

Emily. These explanations are very satisfactory; but allow me to ask you one more question respecting the increased levity of heated liquids. You said that when water was heated over the fire, the particles at the bottom of the vessel ascended as soon as heated, in consequence of their specific levity: why does not the same effect continue when the water boils, and is converted into steam? and why does the steam rise from the surface, instead of the bottom of the liquid?

Mrs. B. The steam or vapour does ascend from the bottom, though it seems to arise from the surface of the liquid. We shall boil some water in this Florence flask, (Plate IV. Fig. 1.) in order that you may be well acquainted with the process of ebullition;—you will then see, through the glass, that the vapour rises in bubbles from the bottom. We shall make it boil by means of a lamp, which is more convenient for this purpose than the chimney fire.

Emily. I see some small bubbles ascend, and a great many appear all over the inside of the flask; does the water begin to boil already?

Mrs. B. No; what you now see are bubbles of air, which were either dissolved in the water, or attached to the inner surface of the flask, and which, being rarefied by the heat, ascend in the water.

Emily. But the heat which rarefies the air inclosed in the water must rarefy the water at the same time; therefore, if it could remain stationary in the water when both were cold, I do not understand why it should not when both are equally heated?

Mrs. B. Air being much less dense than water, is more easily rarefied; the former, therefore, expands to a great extent, whilst the latter continues to occupy nearly the same space; for water dilates comparatively but very little without changing its state and becoming vapour. Now that the water in the flask begins to boil, observe what large bubbles rise from the bottom of it.

Emily. I see them perfectly; but I wonder that they have sufficient power to force themselves through the water.

Caroline. They *must* rise, you know, from their specific levity.

Mrs. B. You are right, Caroline; but vapour has not in all liquids (when brought to the degree of vaporization) the power of overcoming the pressure of the less heated surface. Metals, for instance, mercury excepted, evaporate only from the surface; therefore no vapour will ascend from them till the degree of heat which is necessary to form it has reached the surface; that is to say, till the whole of the liquid is brought to a state of ebullition.

Emily. I have observed that steam, immediately issuing from the spout of a tea-kettle, is less visible than at a further distance from it; yet it must be more dense when it first evaporates, than when it first begins to diffuse itself in the air.

Mrs. B. When the steam is first formed, it is so perfectly dissolved by caloric, as to be invisible. In order however to understand this, it will be necessary for me to enter into some explanation respecting the nature of SOLUTION. Solution takes place whenever a body is melted in a fluid. In this operation the body is reduced to such a minute state of division by the fluid, as to become invisible in it, and to partake of its fluidity; but in common solutions this happens without any decomposition, the body being only divided into its integrant particles by the fluid in which it is melted.

Caroline. It is then a mode of destroying the attraction of aggregation.

Mrs. B. Undoubtedly.—The two principal solvent fluids are *water* and *caloric.* You may have observed that if you melt salt in water it totally disappears, and the water remains clear, and transparent as before; yet though the union of these two bodies appears so perfect, it is not produced by any chemical combination; both the salt and the water remain unchanged; and if you were to separate them by evaporating the latter, you would find the salt in the same state as before.

Emily. I suppose that water is a solvent for solid bodies, and caloric for liquids?

Mrs. B. Liquids of course can only be converted into vapour by caloric. But the solvent power of this agent is not at all confined to that class of bodies; a great variety of solid substances are dissolved by heat: thus metals, which are insoluble in water, can be dissolved by intense heat, being first fused or converted into a liquid, and then rarefied into an invisible vapour. Many other bodies, such as salt, gums, &c. yield to either of these solvents.

Caroline. And that, no doubt, is the reason why hot water will melt them so much better than cold water?

Mrs. B. It is so. Caloric may, indeed, be considered as having, in every instance, some share in the solution of a body by water, since water, however low its temperature may be, always contains more or less caloric.

Emily. Then, perhaps, water owes its solvent power merely to the caloric contained in it.

Mrs. B. That, probably, would be carrying the speculation too far; I should rather think that water and caloric unite their efforts to dissolve a body, and that the difficulty or facility of effecting this, depend both on the degree of attraction of aggregation to be overcome, and on the arrangement of the particles which are more or less disposed to be divided and penetrated by the solvent.

Emily. But have not all liquids the same solvent power as water?

Mrs. B. The solvent power of other liquids varies according to their nature, and that of the substances submitted to their action. Most of these solvents, indeed, differ essentially from water, as they do not merely separate the integrant particles of the bodies which they dissolve, but attack their constituent principles by the power of chemical attraction, thus producing a true decomposition. These more complicated operations we must consider in another place, and confine our attention at present to the solutions by water and caloric.

Caroline. But there are a variety of substances which, when dissolved in water, make it thick and muddy, and destroy its transparency.

Mrs. B. In this case it is not a solution, but simply a mixture. I shall show you the difference between a solution and a mixture, by putting some common salt into one glass of water, and some powder of chalk into another; both these substances are white, but their effect on the water will be very different.

Caroline. Very different indeed! The salt entirely disappears and leaves the water transparent, whilst the chalk changes it into an opaque liquid like milk.

Emily. And would lumps of chalk and salt produce similar effects on water?

Mrs. B. Yes, but not so rapidly: salt is, indeed, soon melted though in a lump; but chalk, which does not mix so readily with water, would require a much greater length of time; I therefore preferred showing you the experiment with both substances reduced to powder, which does not, in any respect alter their nature, but facilitates the operation merely by presenting a greater quantity of surface to the water.

I must not forget to mention a very curious circumstance respecting solutions, which is, that a fluid is not nearly so much increased in bulk by holding a body in solution, as it would by mere mixture with the body.

Caroline. That seems impossible; for two bodies cannot exist together in the same space.

Mrs. B. Two bodies may, by condensation, occupy less space when in union than when separate, and this I can show you by an easy experiment.

This phial, which contains some salt, I shall fill with water, pouring it in quickly, so as not to dissolve much of the salt; and when it is quite full I cork it.—If I now shake the phial till the salt is dissolved, you will observe that it is no longer full.

Caroline. I shall try to add a little more salt.—But now, you see, Mrs. B., the water runs over.

Mrs. B. Yes; but observe that the last quantity of salt you put in remains solid at the bottom, and displaces the water; for it has already melted all the salt it is capable of holding in solution. This is called the point of *saturation;* and the water in this case is said to be *saturated* with salt.

Emily. I think I now understand the solution of a solid body by water perfectly; but I have not so clear an idea of the solution of a liquid by caloric.

Mrs. B. It is probably of a similar nature; but as caloric is an invisible fluid, its action as a solvent is not so obvious as that of water. Caloric, we may conceive, dissolves water, and converts it into vapour by the same process as water dissolves salt-that is to say, the particles of water are so minutely divided by the caloric as to become invisible. Thus, you are now enabled to understand why the vapour of boiling water, when it first issues from the spout of a kettle, is invisible; it is so, because it is then completely dissolved by caloric. But the air with which it comes in contact, being much colder than the vapour, the latter yields to it a quantity of its caloric. The particles of vapour being thus in a great measure deprived of their solvent, gradually collect, and become visible in the form of steam, which is water in a state of imperfect solution; and if you were further to deprive it of its caloric, it would return to its original liquid state.

Caroline. That I understand very well. If you hold a cold plate over a tea-urn, the steam issuing from it will be immediately converted into drops of water by parting with its caloric to the plate; but in what state is the steam, when it becomes invisible by being diffused in the air?

Mrs. B. It is not merely diffused, but is again dissolved by the air.

Emily. The air, then, has a solvent power, like water and caloric?

Mrs. B. This was formerly believed to be the case. But it appears from more recent enquiries that the solvent power of the atmosphere depends solely upon the caloric contained in it. Sometimes the watery vapour diffused in the atmosphere is but imperfectly dissolved, as is the case in the formation of clouds and fogs; but if it gets into a region sufficiently warm, it becomes perfectly invisible.

Emily. Can any water dissolve in the atmosphere without its being previously converted into vapour by boiling?

Mrs. B. Unquestionably; and this constitutes the difference between *vaporization* and *evaporation*. Water, when heated to the boiling point, can no longer exist in the form of water, and must necessarily be converted into vapour or steam, whatever may be the state and temperature of the surrounding medium; this is called vaporization. But the atmosphere, by means of the caloric it contains, can take up a certain portion of water at any temperature, and hold it in a state of solution. This is simply evaporation. Thus the atmosphere is continually carrying off moisture from the surface of the earth, until it is saturated with it.

Caroline. That is the case, no doubt, when we feel the atmosphere damp.

Mrs. B. On the contrary, when the moisture is well dissolved it occasions no humidity: it is only when in a state of imperfect solution and floating in the atmosphere, in the form of watery vapour, that it produces dampness. This happens more frequently in winter than in summer; for the lower the temperature of the atmosphere, the less water it can dissolve; and in reality it never contains so much moisture as in a dry hot summer's day.

Caroline. You astonish me! But why, then, is the air so dry in frosty weather, when its temperature is at the lowest?

Emily. This, I conjecture, proceeds not so much from the moisture being dissolved, as from its being frozen;* is not that the case?

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* In cold climates, when there is not a cloud to be seen, and the sun rises in all his glory, the air is sometimes full of little particles of ice, glistening in every direction, and forming a most beautiful spectacle. This is owing to the condensation, and freezing of the particles of water in the air, by the intense cold. C.

Mrs. B. It is; and the freezing of the watery vapour which the atmospheric heat could not dissolve, produces what is called a hoar frost; for the particles descend in freezing, and attach themselves to whatever they meet with on the surface of the earth.

The tendency of free caloric to an equilibrium, together with its solvent power, are likewise connected the phenomena of rain, of dew, &c. When moist air of a certain temperature happens to pass through a colder region of the atmosphere, it parts with a portion of its heat to the surrounding air; the quantity of caloric, therefore, which served to keep the water in a state of vapour, being diminished, the watery particles approach each other, and form themselves into drops of water, which being heavier than the atmosphere, descend to the earth. There are also other circumstances, and particularly the variation in the weight of the atmosphere, which may contribute to the formation of rain. This, however, is an intricate subject, into which we cannot more fully enter at present.

Emily. In what manner do you account for the formation of dew?

Mrs. B. Dew is a deposition of watery particles or minute drops from the atmosphere, precipitated by the coolness of the evening.

Caroline. This precipitation is owing, I suppose, to the cooling of the atmosphere, which prevents its retaining so great a quantity of watery vapour in solution as during the heat of the day.

Mrs. B. Such was, from time immemorial, the generally received opinion respecting the cause of dew; but it has been very recently proved by a course of ingenious experiments of Dr. Wells, that the deposition of dew is produced by the cooling of the surface of the earth, which he has shown to take place previously to the cooling of the atmosphere; for on examining the temperature of a plot of grass just before the dew-fall, he found that it was considerably colder than the air a few feet above it, from which the dew was shortly after precipitated.

Emily. But why should the earth cool in the evening sooner than the atmosphere?

Mrs. B. Because it parts with its heat more readily than the air; the earth is an excellent radiator of caloric, whilst the atmosphere does not possess that property, at least in any sensible degree. Towards evening, therefore, when the solar heat declines, and when after sunset it entirely ceases, the earth rapidly cools by radiating heat towards the skies; whilst the air has no means of parting with its heat but by coming into contact with the cooled surface of the earth, to which it communicates its caloric. Its solvent power being thus reduced, it is unable to retain so large a portion of watery vapour, and deposits those pearly drops which we call dew.

Emily. If this be the cause of dew, we need not be apprehensive of receiving any injury from it; for it can be deposited only on surfaces that are colder than the atmosphere, which is never the case with our bodies.

Mrs. B. Very true; yet I would not advise you for this reason to be too confident of escaping all the ill effects which may arise from exposure to the dew; for it may be deposited on your clothes, and chill you afterwards by its evaporation from them. Besides, whenever the dew is copious, there is a chill in the atmosphere which it is not always safe to encounter.

Caroline. Wind, then, must promote the deposition of dew, by bringing a more rapid succession of particles of air in contact with the earth, just as it promotes the cooling of the earth and warming of the atmosphere during the heat of the day?

Mrs. B. Yes; provided the wind be unattended with clouds, for these accumulations of moisture not only prevent the free radiation of the earth towards the upper regions, but themselves radiate towards the earth; under these circumstances much less dew is formed than on fine clear nights, when the radiation of the earth passes without obstacle through the atmosphere to the distant regions of space, whence it receives no caloric in exchange. The dew continues to be deposited during the night, and is generally most abundant towards morning; when the contrast between the temperature of the earth and that of the air is greatest. After sunrise the equilibrium of temperature between these two bodies is gradually restored by the solar rays passing freely through the atmosphere to the earth; and later in the morning the temperature of the earth gains the ascendency, and gives out caloric to the air by contact, in the same manner as it receives it from the air during the night.

Can you tell me, now, why a bottle of wine taken fresh from the cellar (in summer particularly,) will soon be covered with dew; and even the glasses into which the wine is poured will be moistened with a similar vapour?

Emily. The bottle being colder than the surrounding air, must absorb caloric from it; the moisture therefore which that air contained becomes visible, and forms the dew which is deposited on the bottle.

Mrs. B. Very well, Emily. Now, Caroline, can you inform me why, in a warm room, or close carriage, the contrary effect takes place; that is to say, that the inside of the windows is covered with vapour?

Caroline. I have heard that it proceeds from the breath of those within the room or the carriage; and I suppose it is occasioned by the windows which, being colder than the breath, deprive it of part of its caloric, and by this means convert it into watery vapour.

Mrs. B. You have both explained it extremely well. Bodies attract dew in proportion as they are good radiators of caloric, as it is this quality which reduces their temperature below that of the atmosphere; hence we find that little or no dew is deposited on rocks, sand, water; while grass and living vegetables, to which it is so highly beneficial, attract it in abundance—another remarkable instance of the wise and bountiful dispensations of Providence.

Emily. And we may again observe it in the abundance of dew in summer, and in hot climates, when its cooling effects are so much required; but I do not understand what natural cause increases the dew in hot weather?

Mrs. B. The more caloric the earth receives during the day, the more it will radiate afterwards, and consequently the more rapidly its temperature will be reduced in the evening, in comparison to that of the atmosphere. In the West Indies especially, where the intense heat of the day is strongly contrasted with the coolness of the evening, the dew is prodigiously abundant. During a drought, the dew is less plentiful, as the earth is not sufficiently supplied with moisture to be able to saturate the atmosphere.

Caroline. I have often observed, Mrs. B., that when I walk out in frosty weather, with a veil over my face, my breath freezes upon it. Pray what is the reason of that?

Mrs. B. It is because the cold air immediately seizes on the caloric of your breath, and by robbing it of its solvent, reduces it to a denser fluid, which is the watery vapour that settles on your veil, and there it continues parting with its caloric till it is brought down to the temperature of the atmosphere, and assumes the form of ice.

You may, perhaps, have observed that the breath of animals, or rather the moisture contained in it, is visible in damp weather, or during a frost. In the former case, the atmosphere being over-saturated with moisture, can dissolve no more. In the latter, the cold condenses it into visible vapour; and for the same reason, the steam arising from water that is warmer than the atmosphere, becomes visible. Have you never taken notice of the vapour rising from your hands after having dipped them into warm water?

Caroline. Frequently, especially in frosty weather.

Mrs. B. We have already observed that pressure is an obstacle to evaporation: there are liquids which contain so great a quantity of caloric, and whose particles consequently adhere so slightly together, that they may be rapidly converted into vapour without any elevation of temperature, merely by taking off the weight of the atmosphere. In such liquids, you perceive, it is the pressure of the atmosphere alone that connects their particles, and keeps them in a liquid state.

Caroline. I do not well understand why the particles of such fluids should be disunited and converted into vapour, without any elevation of temperature, in spite of the attraction of cohesion.

Mrs. B. It is because the degree of heat at which we usually observe these fluids is sufficient to overcome their attraction of cohesion. Ether is of this description; it will boil and be converted into vapour, at the common temperature of the air, if the pressure of the atmosphere be taken off.

Emily. I thought that ether would evaporate without either the pressure of the atmosphere being taken away, or heat applied; and that it was for that reason so necessary to keep it carefully corked up?

Mrs. B. It is true it will evaporate, but without ebullition; what I am now speaking of is the vaporization of ether, or its conversion into vapour by boiling. I am going to show you how suddenly the ether in this phial will be converted into vapour, by means of the air-pump.—Observe with what rapidity the bubbles ascend, as I take off the pressure of the atmosphere.

Caroline. It positively boils: how singular to see a liquid boil without heat!

Mrs. B. Now I shall place the phial of ether in this glass, which it nearly fits, so as to leave only a small space, which I fill with water; and in this state I put it again under the receiver. (PLATE IV. Fig. 1.)*—You will observe, as I exhaust the air from it, that whilst the ether boils, the water freezes.

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* Two pieces of thin glass tubes, sealed at one end might answer this purpose better. The experiment, however, as here described, is difficult, and requires a very nice apparatus. But if, instead of phials or tubes, two watch glasses be used, water may be frozen almost instantly in the same manner. The two glasses are placed over one another, with a few drops of water interposed between them, and the uppermost glass is filled with ether. After working the pump for a minute or two, the glasses are found to adhere strongly together, and a thin layer of ice is seen between them.

Caroline. It is indeed wonderful to see water freeze in contact with a boiling fluid!

Emily. I am at a loss to conceive how the ether can pass to the state of vapour without an addition of caloric. Does it not contain more caloric in a state of vapour, than in a state of liquidity?

Mrs. B. It certainly does; for though it is the pressure of the atmosphere which condenses it into a liquid, it is by forcing out the caloric that belongs to it when in an aëriform state.

Emily. You have, therefore, two difficulties to explain, Mrs. B.—First, whence the ether obtains the caloric necessary to convert it into vapour when it is relieved from the pressure of the atmosphere; and, secondly, what is the reason that the water, in which the bottle of ether stands, is frozen?

Caroline. Now, I think, I can answer both these questions. The ether obtains the addition of caloric required, from the water in the glass; and the loss of caloric, which the latter sustains, is the occasion of its freezing.

Mrs. B. You are perfectly right; and if you look at the thermometer which I have placed in the water, whilst I am working the pump, you will see that every time bubbles of vapour are produced, the mercury descends; which proves that the heat of the water diminishes in proportion as the ether boils.

Emily. This I understand now very well; but if the water freezes in consequence of yielding its caloric to the ether, the equilibrium of heat must, in this case, be totally destroyed. Yet you have told us, that the exchange of caloric between two bodies of equal temperature, was always equal; how, then, is it that the water, which was originally of the same temperature as the ether, gives out caloric to it, till the water is frozen, and the ether made to boil?

Mrs. B. I suspected that you would make these objections; and, in order to remove them, I enclosed two thermometers in the air-pump; one of which stands in the glass of water, the other in the phial of ether; and you may see that the equilibrium of temperature is not destroyed; for as the thermometer descends in the water, that in the ether sinks in the same manner; so that both thermometers indicate the same temperature, though one of them is in a boiling, the other in a freezing liquid.

Emily. The ether, then, becomes colder as it boils? This is so contrary to common experience, that I confess it astonishes me exceedingly.

Caroline. It is, indeed, a most extraordinary circumstance. But pray, how do you account for it?

Mrs. B. I cannot satisfy your curiosity at present; for before we can attempt to explain this apparent paradox, it is necessary to become acquainted with the subject of LATENT HEAT; and that, I think, we must defer till our next interview.

Caroline. I believe, Mrs. B., that you are glad to put off the explanation; for it must be a very difficult point to account for.

Mrs. B. I hope, however, that I shall do it to your complete satisfaction.

Emily. But before we part, give me leave to ask you one question. Would not water, as well as ether, boil with less heat, if deprived of the pressure of the atmosphere?

Mrs. B. Undoubtedly. You must always recollect that there are two forces to overcome, in order to make a liquid boil or evaporate; the attraction of aggregation, and the weight of the atmosphere. On the summit of a high mountain (as Mr. De Saussure ascertained on Mount Blanc) much less heat is required to make water boil, than in the plain, where the weight of the atmosphere is greater.* Indeed if the weight of the atmosphere be entirely removed by means of a good air-pump, and if water be placed in the exhausted receiver, it will evaporate so fast, however cold it may be, as to give it the appearance of boiling from the surface. But without the assistance of the air-pump, I can show you a very pretty experiment, which proves the effect of the pressure of the atmosphere in this respect.

Observe, that this Florence flask is about half full of water, and the upper half of invisible vapour, the water being in the act of boiling.—I take it from the lamp, and cork it carefully—the water, you see, immediately ceases boiling.—I shall now dip the flask into a bason of cold water.†

Caroline. But look, Mrs. B., the hot water begins to boil again, although the cold water must rob it more and more of its caloric? What can be the reason of that?

Mrs. B. Let us examine its temperature. You see the thermometer immersed in it remains stationary at 150 degrees, which is about 30 degrees below the boiling point. When I took the flask from the lamp, I observed to you that the upper part of it was filled with vapour; this being compelled to yield its caloric to the cold water, was again condensed into water.— What, then, filled the upper part of the flask?

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* On the top of Mount Blanc, water boiled when heated only to 187 degrees, instead of 212 degrees.

† The same effect may be produced by wrapping a cold wet linen cloth round the upper part of the flask. In order to show how much the water cools whilst it is boiling, a thermometer, graduated on the tube itself, may be introduced into the bottle through the cork.

Emily. Nothing; for it was too well corked for the air to gain admittance, and therefore the upper part of the flask must be a vacuum.

Mrs. B. The water below, therefore, no longer sustains the pressure of the atmosphere, and will consequently boil at a much lower temperature. Thus, you see, though it had lost many degrees of heat, it began boiling again the instant the vacuum was formed above it. The boiling has now ceased, the temperature of the water being still farther reduced; if it had been ether, instead of water, it would have continued boiling much longer, for ether boils, under the usual atmospheric pressure, at a temperature as low as 100 degrees; and in a vacuum it boils at almost any temperature; but water being a more dense fluid, requires a more considerable quantity of caloric to make it evaporate quickly, even when the pressure of the atmosphere is removed.

Emily. What proportion of vapour can the atmosphere contain in a state of solution?

Mrs. B. I do not know whether it has been exactly ascertained by experiment; but at any rate this proportion must vary, both according to the temperature and the weight of the atmosphere; for the lower the temperature, and the greater the pressure, the smaller must be the proportion of vapour that the atmosphere can contain.

To conclude the subject of free caloric, I should mention *Ignition*, by which s meant that emission of light which is produced in bodies at a very high temperature, and which is the effect of accumulated caloric.

Emily. You mean, I suppose, that light which is produced by a burning body?

Mrs. B. No: ignition is quite independent of combustion. Clay, chalk, and indeed all incombustible substances, may be made red hot. When a body burns, the light emitted is the effect of a chemical change which takes place, whilst ignition is the effect of caloric alone, and no other change than that of temperature is produced in the ignited body.

All solid bodies, and most liquids, are susceptible of ignition, or, in other words, of being heated so as to become luminous; and it is remarkable that this takes place pretty nearly at the same temperature in all bodies, that is, at about 800 degrees of Fahrenheit's scale.

Emily. But how can liquids attain so high a temperature, without being converted into vapour?

Mrs. B. By means of confinement and pressure. Water confined in a strong iron vessel (called Papin's digester) can have its temperature raised to upwards of 400 degrees. Sir James Hall has made some very curious experiments on the effects of heat assisted by pressure; by means of strong gun-barrels, he succeeded in melting a variety of substances which were considered as infusible; and it is not unlikely that, by similar methods, water itself might be heated to redness.

Emily. I am surprised at that: for I thought that the force of steam was such as to destroy almost all mechanical resistance.

Mrs. B. The expansive force of steam is prodigious; but in order to subject water to such high temperatures, it is prevented by confinement from being converted into steam, and the expansion of heated water is comparatively trifling.—But we have dwelt so long on the subject of free caloric, that we must reserve the other modifications of that agent to our next meeting, when we shall endeavour to proceed more rapidly.

CONVERSATION IV.

ON COMBINED CALORIC, COMPREHENDING SPECIFIC AND LATENT HEAT.

Mrs. B. We are now to examine the other modifications of caloric.

Caroline. I am very curious to know of what nature they can be; for I have no notion of any kind of heat that is not perceptible to the senses.

Mrs. B. In order to enable you to understand them, it will be necessary to enter into some previous explanations.

It has been discovered by modern chemists, that bodies of a different nature, heated to the same temperature, do not contain the same quantity of caloric.

Caroline. How could that be ascertained? Have you not told us that it is impossible to discover the absolute quantity of caloric which bodies contain?

Mrs. B. True; but at the same time I said that we were enabled to form a judgment of the proportions which bodies bore to each other in this respect. Thus it is found that, in order to raise the temperature of different bodies the same number of degrees, different quantities of caloric are required for each of them. If, for instance, you place a pound of lead, a pound of chalk, and a pound of milk, in a hot oven, they will be gradually heated to the temperature of the oven; but the lead will attain it first, the chalk next, and the milk last.

Caroline. That is a natural consequence of their different bulks; the lead, being the smallest body, will be heated soonest, and the milk, which is the largest, will require the longest time.

Mrs. B. That explanation will not do, for if the lead be the least in bulk, it offers also the least surface to the caloric, the quantity of heat therefore which can enter into it in the same space of time is proportionally smaller.

Emily. Why, then, do not the three bodies attain the temperature of the oven at the same time?

Mrs. B. It is supposed to be on account of the different capacity of these bodies for caloric.

Caroline. What do you mean by the *capacity* of a body for caloric?

Mrs. B. I mean a certain disposition of bodies to require more or less caloric for raising their temperature to any degree of heat. Perhaps the fact may be thus explained:

Let us put as many marbles into this glass as it will contain, and pour some sand over them—observe how the sand penetrates and lodges between them. We shall now fill another glass with pebbles of various forms—you see that they arrange themselves in a more compact manner than the marbles, which, being globular, can touch each other by a single point only. The pebbles therefore, will not admit so much sand between them; and consequently one of these glasses will necessarily contain more sand than the other, though both of them be equally full.

Caroline. This I understand perfectly. The marbles and the pebbles represent two bodies of different kinds, and the sand the caloric contained in them; and it appears very plain, from this comparison, that one body may admit of more caloric between its particles than another.

Mrs. B. You can no longer be surprised, therefore, that bodies of a different capacity for caloric should require different proportions of that fluid to raise their temperatures equally.

Emily. But I do not conceive why the body that contains the most caloric should not be of the highest temperature; that is to say, feel hot in proportion to the quantity of caloric it contains.

Mrs. B. The caloric that is employed in filling the capacity of a body, is not free caloric; but is imprisoned as it were in the body, and is therefore imperceptible: for we can feel only the caloric which the body parts with, and not that which it retains.

Caroline. It appears to me very extraordinary that heat should be confined in a body in such a manner as to be imperceptible.

Mrs. B. If you lay your hand on a hot body, you feel only the caloric which leaves it, and enters your hand; for it is impossible that you should be sensible of that which remains in the body. The thermometer, in the same manner, is affected only by the free caloric which a body transmits to it, and not at all by that which it does not part with.

Caroline. I begin to understand it: but I confess that the idea of insensible heat is so new and strange to me, that it requires some time to render it familiar.

Mrs. B. Call it insensible caloric, and the difficulty will appear much less formidable. It is indeed a sort of contradiction to call it heat, when it is so situated as to be incapable of producing that sensation. Yet this modification of caloric is commonly called SPECIFIC HEAT.

Caroline. But it certainly would have been more correct to have called it *specifiic caloric.*

Emily. I do not understand how the term *specific* applies to this modification of caloric?

Mrs. B. It expresses the relative quantity of caloric which different *species* of bodies of the same weight and temperature are capable of containing. This modification is also frequently called *heat of capacity*, a term perhaps preferable, as it explains better its own meaning.

You now understand, I suppose, why the milk and chalk required a longer portion of time than the lead to raise their temperature to that of the oven?

Emily. Yes: the milk and chalk having a greater capacity for caloric than the lead, a greater proportion of that fluid became insensible in those bodies: and the more slowly, therefore, their temperature was raised.

Caroline. But might not this difference proceed from the different conducting powers of heat in these three bodies, since that which is the best conductor must necessarily attain the temperature of the oven first?

Mrs. B Very well observed, Caroline. This objection would be insurmountable, if we could not, by reversing the experiment, prove that the milk, the chalk, and the lead, actually absorbed different quantities of caloric, and we know that if the different time they took in heating, proceeded merely from their different conducting powers, they would each have acquired an equal quantity of caloric.

Caroline. Certainly. But how can you reverse this experiment?

Mrs. B. It may be done by cooling the several bodies to the same degree in an apparatus adapted to receive and measure the caloric which they give out. Thus, if you plunge them into three equal quantities of water, each at the same temperature, you will be able to judge of the relative quantity of caloric which the three bodies contained, by that, which, in cooling, they communicated to their respective portions of water: for the same quantity of caloric which they each absorbed to raise their temperature, will abandon them in lowering it; and on examining the three vessels of water, you will find the one in which you immersed the lead to be the least heated; that which held the chalk will be the next; and that which contained the milk will be heated the most of all. The celebrated Lavoisier has invented a machine to estimate, upon this principle, the specific heat of bodies in a more perfect manner; but I cannot explain it to you, till you are acquainted with the next modification of caloric.

Emily. The more dense a body is, I suppose, the less is its capacity for caloric?

Mrs. B. This is not always the case with bodies of different nature; iron, for instance, contains more specific heat than tin, though it is more dense. This seems to show that specific heat does not merely depend upon the interstices between the particles; but, probably, also upon some peculiar constitution of the bodies which we do not comprehend.

Emily. But, Mrs. B., it would appear to me more proper to compare bodies by *measure*, rather than by *weight*, in order to estimate their specific heat. Why, for instance, should we not compare *pints* of milk, of chalk, and of lead, rather than *pounds* of those substances; for equal weights may be composed of very different quantities?

Mrs. B. You are mistaken, my dear; equal weight must contain equal quantities of matter; and when we wish to know what is the relative quantity of caloric which substances of various kinds are capable of containing under the same temperature, we must compare equal weights, and not equal bulks of those substances. Bodies of the same weight may undoubtedly be of very different dimensions; but that does not change their real quantity of matter. A pound of feathers does not contain one atom more than a pound of lead.

Caroline. I have another difficulty to propose. It appears to me, that if the temperature of the three bodies in the oven did not rise equally, they would never reach the same degree; the lead would always keep its advantage over the chalk and milk, and would perhaps be boiling before the others had attained the temperature of the oven. I think you might as well say that, in the course of time, you and I should be of the same age?

Mrs. B. Your comparison is not correct, Caroline. As soon as the lead reached the temperature of the oven, it would remain stationary; for it would then give out as much heat as it would receive. You should recollect that the exchange of radiating heat, between two bodies of equal temperature, is equal: it would be impossible, therefore, for the lead to accumulate heat after having attained the temperature of the oven; and that of the chalk and milk therefore would ultimately arrive at the same standard. Now I fear that this will not hold good with respect to our ages, and that, as long as I live, I shall never cease to keep my advantage over you.

Emily. I think that I have found a comparison for specific heat, which is very applicable. Suppose that two men of equal weight and bulk, but who required different quantities of food to satisfy their appetites, sit down to dinner, both equally hungry; the one would consume a much greater quantity of provisions than the other, in order to be equally satisfied.

Mrs. B. Yes, that is very fair; for the quantity of food necessary to satisfy their respective appetites, varies in the sume manner as the quantity of caloric requisite to raise equally the temperature of different bodies.

Emily. The thermometer, then, affords no indication of the specific heat of bodies?

Mrs. B. None at all: no more than satiety is a test of the quantity of food eaten. The thermometer, as I have repeatedly said, can be affected only by free caloric, which alone raises the temperature of bodies.

But there is another mode of proving the existence of specific heat, which affords a very satisfactory illustration of that modification. This, however, I did not enlarge upon before, as I thought it might appear to you rather complicated.—If you mix two fluids of different temperatures, let us say the one at 50 degrees, and the other at 100 degrees, of what temperature do you suppose the mixture will be?

Caroline. It will be no doubt the medium between the two, that is to say, 75 degrees.

Mrs. B. That will be the case if the two bodies happen to have the same capacity for caloric; but if not, a different result will be obtained. Thus, for instance, if you mix together a pound of mercury, heated at 50 degrees, and a pound of water heated at 100 degrees, the temperature of the mixture, instead of being 75 degrees, will be 80 degrees; so that the water will have lost only 12 degrees, whilst the mercury will have gained 38 degrees; from which you will conclude that the capacity of mercury for heat is less than that of water.

Caroline. I wonder that mercury should have so little specific heat. Did we not see it was a much better conductor of heat than water?

Mrs. B. And it is precisely on that account that its specific heat is less. For since the conductive power of bodies depends, as we have observed before, on their readiness to receive heat and part with it, it is natural to expect that those bodies which are the worst conductors should absorb the most caloric before they are disposed to part with it to other bodies. But let us now proceed to LATENT HEAT.

Caroline. And pray what kind of heat is that?

Mrs. B. It is another modification of combined caloric, which is so analogous to specific heat, that most chemists make no distinction between them; but Mr. Pictet, in his Essay on Fire, has so clearly discriminated them, that I am induced to adopt his view of the subject. We therefore call *latent heat* that portion of insensible caloric which is employed in changing the state of bodies; that is to say, in converting solids into liquids, or liquids into vapour. When a body changes its state from solid to liquid, or from liquid to vapour, its expansion occasions a sudden and considerable increase of capacity for heat, in consequence of which it immediately absorbs a quantity of caloric, which becomes fixed in the body it has transformed; and, as it is perfectly concealed from our senses, it has obtained the name of *latent* heat.

Caroline. I think it would be much more correct to call this modification latent caloric instead of latent heat, since it does not excite the sensation of heat.

Mrs. B. This modification of heat was discovered and named by Dr. Black long before the French chemists introduced the term caloric, and we must not presume to alter it, as it is still used by much better chemists than ourselves. Besides, you are not to suppose that the nature of heat is altered by being variously modified: for if latent heat and specific heat do not excite the same sensations as free caloric, it is owing to their being in a state of confinement, which prevents them from acting upon our organs; and consequently, as soon as they are extricated from the body in which they are imprisoned, they return to their state of free caloric.

Emily. But I do not yet clearly see in what respect latent heat differs from specific heat; for they are both of them imprisoned and concealed in bodies.

Mrs. B. Specific heat is that which is employed in filling the capacity of a body for caloric, in the state in which this body actually exists; while latent heat is that which is employed only in effecting a change of state, that is, in converting bodies from a solid to a liquid, or from a liquid to an aëriform state. But I think that, in a general point of view, both these modifications might be comprehended under the name of *heat of capacity*, as in both cases the caloric is equally engaged in filling the capacities of bodies.

I shall now show you an experiment, which I hope will give you a clear idea of what is understood by latent heat.

The snow which you see in this phial has been cooled by certain chemical means (which I cannot well explain to you at present,) to five or six degrees below the freezing point, as you will find indicated by the thermometer which is placed in it. We shall expose it to the heat of a lamp, and you will see the thermometer gradually rise, till it reaches the freezing point ——

Emily. But there it stops, Mrs. B., and yet the lamp burns just as well as before. Why is not its heat communicated to the thermometer?

Caroline. And the snow begins to melt, therefore it must be rising above the freezing point?

Mrs. B. The heat no longer affects the thermometer, because it is wholly employed in converting the ice into water. As the ice melts, the caloric becomes *latent* in the new-formed liquid, and therefore cannot raise its temperature; and the thermometer will consequently remain stationary, till the whole of the ice be melted.

Caroline. Now it is all melted, and the thermometer begins to rise again.

Mrs. B. Because the conversion of the ice into water being completed, the caloric no longer becomes latent; and therefore the heat which the water now receives raises its temperature, as you find the thermometer indicates.

Emily. But I do not think that the thermometer rises so quickly in the water as it did in the ice, previous to its beginning to melt, though the lamp burns equally well?

Mrs. B. That is owing to the different specific heat of ice and water. The capacity of water for caloric being greater than that of ice, more heat is required to raise its temperature, and therefore the thermometer rises slower in the water than in the ice.

Emily. True; you said that a solid body always increased its capacity for heat by becoming fluid; and this is an instance of it.

Mrs. B. Yes; and the latent heat is that which is absorbed in consequence of the greater capacity which the water has for heat, in comparison to ice.

I must now tell you a curious calculation founded on that consideration. I have before observed to you that though the thermometer shows us the comparative warmth of bodies, and enables us to determine the same point at different times and places, it gives us no idea of the absolute quantity of heat in any body. We cannot tell how low it ought to fall by the privation of all heat, but an attempt has been made to infer it in the following manner. It has been found by experiment, that the capacity of water for heat, when compared with that of ice, is as 10 to 9; so that, at the same temperature, ice contains one-tenth of caloric less than water. By experiment also it is observed, that in order to melt ice, there must be added to it as much heat as would, if it did not melt it, raise its temperature 140 degrees.* This quantity of heat is therefore absorbed when the ice, by being converted into water, is made to contain one-ninth more caloric than it did before. Therefore 140 degrees is a ninth part of the heat contained in ice at 30 degrees; and the point of zero, or the absolute privation of heat, must consequently be 1260 degrees below 32 degrees.†

This mode of investigating so curious a question is ingenious, but its correctness is not yet established by similar calculations for other bodies. The points of absolute cold, indicated by this method in various bodies, are very remote from each other; it is however possible, that this may arise from some imperfection in the experiments.

Caroline. It is indeed very ingenious—but we must now attend to our present experiment. The water begins to boil, and the thermometer is again stationary.

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* That is, water contains 140 degrees of heat more than is indicated by the thermometer. C.

† This calculation was made by Dr. Irvine. Dr. Crawford afterwards placed the real zero at 1500 degrees below the 0 of Fahrenheit. Still later Mr. Dalton has turned his attention to the same subject. The mean of his experiments places the real zero 6000 degrees below the freezing point. All this goes to show that very little has yet been demonstrated on this difficult question. C.

Mrs. B. Well, Caroline, it is your turn to explain the phenomenon.

Caroline. It is wonderfully curious! The caloric is now busy in changing the water into steam, in which it hides itself, and becomes insensible. This is another example of latent heat, producing a change of form. At first it converted a solid body into a liquid, and now it turns the liquid into vapour!

Mrs. B. You see, my dear, how easily you have become acquainted with these modifications of insensible heat, which at first appeared so unintelligible. If, now, we were to reverse these changes, and condense the vapour into water, and the water into ice, the latent heat would re-appear entirely, in the form of free caloric.

Emily. Pray do let us see the effect of latent heat returning to its free state.

Mrs. B. For the purpose of showing this, we need simply conduct the vapour through this tube into this vessel of cold water, where it will part with its latent heat and return to its liquid form.

Emily. How rapidly the steam heats the water!

Mrs. B. That is because it does not merely impart its free caloric to the water, but likewise its latent heat. This method of heating liquids, has been turned to advantage, in several economical establishments. The steam-kitchens, which are getting into such general use, are upon the same principle. The steam is conveyed through a pipe in a similar manner, into the several vessels which contain the provisions to be dressed, where it communicates to them its latent caloric, and returns to the state of water. Count Rumford makes great use of this principle in many of his fire-places: his grand maxim is to avoid all unnecessary waste of caloric, for which purpose he confines the heat in such a manner, that not a particle of it shall unnecessarily escape; and while he economises the free caloric, he takes care also to turn the latent heat to advantage. It is thus that he is enabled to produce a degree of heat superior to that which is obtained in common fire-places, though he employs less fuel.

Emily. When the advantages of such contrivances are so clear and plain, I cannot understand why they are not universally used.

Mrs. B. A long time is always required before innovations, however useful, can be reconciled with the prejudices of the vulgar.

Emily. What a pity it is that there should be a prejudice against new inventions; how much more rapidly the world would improve, if such useful discoveries were immediately and universally adopted !

Mrs. B. I believe, my dear, that there are as many novelties attempted to be introduced, the adoption of which would be prejudicial to society, as there are of those which would be beneficial to it. The well-informed, though by no means exempt from error, have an unquestionable advantage over the illiterate, in judging what is likely or not to prove serviceable; and therefore we find the former more ready to adopt such discoveries as promise to be really advantageous, than the latter, who having no other test of the value of a novelty but time and experience, at first oppose its introduction. The well-informed, however, are frequently disappointed in their most sanguine expectations, and the prejudices of the vulgar, though they often retard the progress of knowledge, yet sometimes, it must be admitted, prevent the propagation of error.—But we are deviating from our subject.

We have converted steam into water, and are now to change water into ice, in order to render the latent heat sensible, as it escapes from the water on its becoming solid. For this purpose we must produce a degree of cold that will make water freeze.

Caroline. That must be very difficult to accomplish in this warm room.

Mrs. B. Not so much as you think. There are certain chemical mixtures which produce a rapid change from the solid to the fluid state, or the reverse, in the substances combined, in consequence of which change latent heat is either extricated or absorbed.

Emily. I do not quite understand you.

Mrs. B. This snow and salt, which you see me mix together, are melting rapidly; heat, therefore, must be absorbed by the mixture, and cold produced.

Caroline. It feels even colder than ice, and yet the snow is melted. This is very extraordinary.

Mrs. B. The cause of the intense cold of the mixture is to be attributed to the change from a solid to a fluid state. The union of the snow and salt produces a new arrangement of their particles, in consequence of which they become liquid; and the quantity of caloric, required to effect this change, is seized upon by the mixture wherever it can be obtained. This eagerness of the mixture for caloric, during its liquefaction, is such, that it converts part of its own free caloric into latent heat, and it is thus that its temperature is lowered.

Emily. Whatever you put in this mixture, therefore, would freeze ?

Mrs. B. Yes; at least any fluid that is susceptible of freezing at that temperature. I have prepared this mixture of salt and snow for the purpose of freezing the water from which you are desirous of seeing the latent heat escape. I have put a thermometer in the glass of water that is to be frozen, in order that you may see how it cools.

Caroline. The thermometer descends, but the heat which the water is now losing, is its *free*, not its *latent* heat.

Mrs. B. Certainly; it does not part with its latent heat till it changes its state and is converted into ice.

Emily. But here is a very extraordinary circumstance! The thermometer has fallen below the freezing point, and yet the water is not frozen.*

Mrs. B. That is always the case previous to the freezing of water when it is in a state of rest. Now it begins to congeal, and you may observe that the thermometer again rises to the freezing point.

Caroline. It appears to me very strange that the thermometer should rise the very moment that the water freezes; for it seems to imply that the water was colder before it froze than when in the act of freezing.

Mrs. B. It is so; and after our long dissertation on this circumstance, I did not think it would appear so surprising to you. Reflect a little, and I think you will discover the reason of it.

Caroline. It must be, no doubt, the extrications of latent heat, at the instant the water freezes, which raises the temperature.

Mrs. B. Certainly; and if you now examine the thermometer, you will find that its rise was but temporary, and lasted only during the disengagement of the latent heat—now that all the water is frozen it falls again, and will continue to fall till the ice and mixture are of an equal temperature.

Emily. And can you show us any experiments in which liquids, by being mixed, become solid, and disengage latent heat?

Mrs. B. I could show you several; but you are not yet sufficiently advanced to understand them well. I shall, however, try one, which will afford you a striking instance of the fact. The fluid which you see in this phial consists of a quantity of a certain salt called *muriat of lime*, dissolved in water. Now, if I pour into it a few drops of this other fluid, called *sulphuric acid*, the whole, or very nearly the whole, will be instantaneously converted into a solid mass.

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* To make this experiment striking, the glass containing the water and thermometer ought to be kept perfectly still until the mercury sinks below the freezing point. Then agitate the water, or drop into it a small piece of ice, and it instantly shoots into crystals, and the thermometer rises. C.

Emily. How white it turns! I feel the latent heat escaping, for the bottle is warm, and the fluid is changed to a solid white substance like chalk!*

Caroline. This is, indeed, the most curious experiment we have seen yet. But pray what is that white vapour which ascends from the mixture?

Mrs. B. You are not yet enough of a chemist to understand that.—But take care, Caroline, do not approach too near it, for it has a very pungent smell.

I shall show you another instance similar to that of the water, which you observed to become warmer as it froze. I have in this phial a solution of a salt called sulphat of soda or Glauber's salt, made very strong, and corked up when it was hot, and kept without agitation till it became cold, as you may feel the phial is. Now when I take out the cork and let the air fall upon it (for being closed when boiling, there was a vacuum in the upper part) observe that the salt will suddenly crystalize. . . .

Caroline. Surprising! how beautifully the needles of salt have shot through the whole phial!

Mrs. B. Yes, it is very striking—but pray do not forget the object of the experiment. Feel how warm the phial has become by the conversion of part of the liquid into a solid.

Emily. Quite warm I declare! this is a most curious experiment of the disengagement of latent heat.

Mrs. B. The slakeing of lime is another remarkable instance of the extrication of latent heat. Have you never observed how quick-lime smokes when water is poured upon it, and how much heat it produces?

Caroline. Yes; but I do not understand what change of state takes place in the lime that occasions its giving out latent heat; for the quick-lime, which is solid, is (if I recollect right) reduced to powder, by this operation, and is, therefore, rather expanded than condensed.

Mrs. B. It is from the water, not the lime, that the latent heat is set free. The water incorporates with, and becomes solid in the lime; in consequence of which the heat, which kept it in a liquid state, is disengaged, and escapes in a sensible form.

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* The *sulphuric* acid by its stronger affinity for the lime, takes it from the *muriatic* acid, unites with it, and forms *sulphate* of lime. The solidity is owing to the insolubility of this last substance in water. The experiment succeeds well, if the water is saturated with the muriate. C.

Caroline. I always thought that the heat originated in the lime. It seems very strange that water, and cold water too, should contain so much heat.

Emily. After this extrication of caloric, the water must exist in a state of ice in the lime, since it parts with the heat which kept it liquid.

Mrs. B. It cannot properly be called ice, since ice implies a degree of cold, at least equal to the freezing point. Yet as water, in combining with lime, gives out more heat than in freezing, it must be in a state of still greater solidity in the lime, than it is in the form of ice; and you may have observed that it does not moisten or liquefy the lime in the smallest degree.

Emily. But, Mrs. B., the smoke that rises is white; if it was only pure caloric which escaped, we might feel, but could not see it.

Mrs. B. This white vapour is formed by some of the particles of lime, in a state of fine dust, which are carried off by the caloric.

Emily. In all changes of state, then, a body either absorbs or disengages latent heat?

Mrs. B. You cannot exactly say *absorbs latent heat*, as the heat becomes latent only on being confined in the body; but you may say, generally, that bodies, in passing from a solid to a liquid form, or from the liquid state to that of vapour, absorb heat; and that when the reverse takes place, heat is disengaged.*

Emily. We can now, I think, account for the ether boiling, and the water freezing in vacuo, at the same temperature.†

Mrs. B. Let me hear you explain it.

Emily. The latent heat, which the water gave out in freezing, was immediately absorbed by the ether, during its conversion into vapour; and therefore, from a latent state in one liquid, it passed into a latent state in the other.

Mrs. B. But this only partly accounts for the result of the experiment; it remains to be explained why the temperature of the ether, while in a state of ebullition, is brought down to the freezing temperature of the water.—It is because the ether, during its evaporation, reduces its own temperature, in the same proportion as that of the water, by converting its free caloric into latent heat; so that, though one liquid boils, and the other freezes, their temperatures remain in a state of equilibrium.

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* This rule, if not universal, admits of very few exceptions.

† See page 48.

Emily. But why does not water, as well as ether, reduce its own temperature by evaporating?

Mrs. B. The fact is that it does, though much less rapidly than ether. Thus, for instance, you may often have observed, in the heat of summer, how much any particular spot may be cooled by watering, though the water used for that purpose be as warm as the air itself. Indeed so much cold may be produced by the mere evaporation of water, that the inhabitants of India, by availing themselves of the most favourable circumstances for this process which their warm climate can afford, namely, the cool of the night, and situations most exposed to the night breeze, succeed in causing water to freeze, though the temperature of the air be as high as 60 degrees. The water is put into shallow earthern trays, so as to expose an extensive surface to the process of evaporation, and in the morning, the water is found covered with a thin cake of ice, which is collected in sufficient quantity to be used for purposes of luxury.

Caroline. How delicious it must be to drink liquids so cold in those tropical climates! But, Mrs. B., could we not try that experiment?

Mrs. B. If we were in the country, I have no doubt but that we should be able to freeze water, by the same means, and under similar circumstances. But we can do it immediately, upon a small scale, in this very room, in which the thermometer stands at 70 degrees. For this purpose we need only place some water in a little cup under the receiver of the air-pump (PLATE V. fig. 1.,) and exhaust the air from it. What will be the consequence, Caroline?

Caroline. Of course the water will evaporate more quickly, since there will no longer be any atmospheric pressure on its surface: but will this be sufficient to make the water freeze?

Mrs. B. Probably not, because the vapour will not be carried off fast enough; but this will be accomplished without difficulty if we introduce into the receiver (fig. 1.,) in a saucer, or other large shallow vessel, some strong sulphuric acid, a substance which has a great attraction for water, whether in the form of vapour, or in the liquid state. This attraction is such that the acid will instantly absorb the moisture as it rises from the water, so as to make room for the formation of fresh vapour; this will of course hasten the process, and the cold produced from the rapid evaporation of the water, will, in a few

Fig. 1.

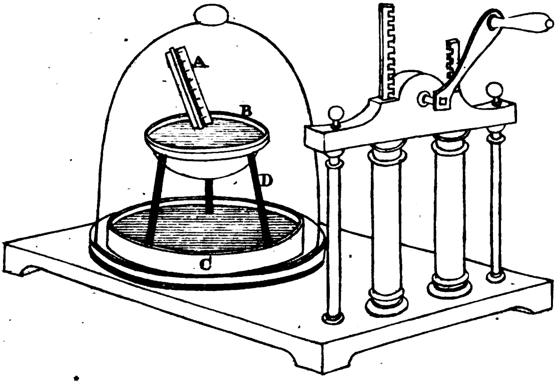

Fig. 2.

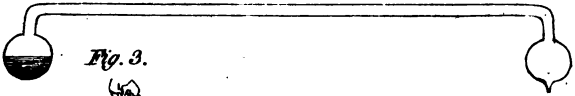

Fig. 3.

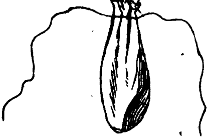

Fig. 5.

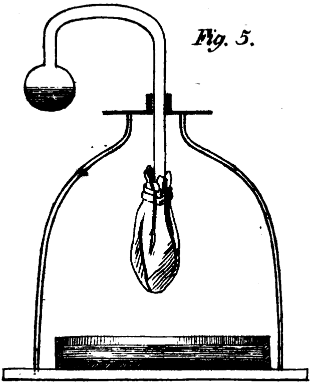

Fig. 4.

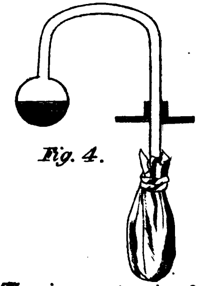

Fig. 1. The air pump & receiver for Mr. Leslie's experiment. C a saucer with sulphuric acid. B a glass or earthen cup containing water. D a stand for the cup with its legs made of glass. A a Thermometer. Fig. 2. Dr. Wolaston's Cryophorus. Fig. 5. Dr. Marcet's mode of using the Cryophorus. Fig. 3. & 4. the different parts of Fig. 5. seen separate.

minutes, be sufficient to freeze its surface.* We shall now exhaust the air from the receiver.

Emily. Thousands of small bubbles already rise through the water from the internal surface of the cup; what is the reason of this?

Mrs. B. These are bubbles of air which were partly attached to the vessel, and partly diffused in the water itself; and they expand and rise in consequence of the atmospheric pressure being removed.

Caroline. See, Mrs. B.; the thermometer in the cup is sinking fast; it has already descended to 40 degrees!

Emily. The water seems now and then violently agitated on the surface, as if it were boiling; and yet the thermometer is descending fast!

Mrs. B. You may call it *boiling* if you please, for this appearance is, as well as boiling, owing to the rapid formation of vapour; but here, as you have just observed, it takes place from the surface, for it is only when heat is applied to the bottom of the vessel that the vapour is formed there.—Now crystals of ice are actually shooting all over the surface of the water.

Caroline. How beautiful it is! The surface is now entirely frozen,—but the thermometer remains at 32 degrees.

Mrs. B. And so it will, conformably with our doctrine of latent heat, until the whole of the water is frozen; but it will then again begin to descend lower and lower, in consequence of the evaporation which goes on from the surface of the ice.

Emily. This is a most interesting experiment; but it would be still more striking if no sulphuric acid were required.

Mrs. B. I will show you a freezing instrument, contrived by Dr. Wollaston, upon the same principle as Mr. Leslie's experiment, by which water may be frozen by its own evaporation alone, without the assistance of sulphuric acid.

This tube, which, as you see (PLATE V. fig. 2.,) is terminated at each extremity by a bulb, one of which is half full of water, is internally perfectly exhausted of air; the consequence of this is, that the water in the bulb is always much disposed to evaporate. This evaporation, however does not proceed sufficiently fast to freeze the water; but if the empty ball be cooled by some artificial means, so as to condense quickly the vapour which rises from the water, the process may be thus so much promoted as to cause the water to freeze in the other ball. Dr. Wollaston has called this instrument *Cryophorus*. [*or Frostbearer. C.*]

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* This experiment was first devised by Mr. Leslie, and has since been modified in a variety of forms.

Caroline. So that cold seems to perform here the same part which the sulphuric acid acted in Mr. Leslie's experiment?

Mrs. B. Exactly so; but let us try the experiment.

Emily. How will you cool the instrument? You have neither ice nor snow.

Mrs. B. True; but we have other means of effecting this.* You recollect what an intense cold can be produced by the evaporation of ether in an exhausted receiver. We shall inclose the bulb in this little bag of fine flannel (fig. 3.), then soak it in ether, and introduce it into the receiver of the air-pump. fig. 5.) For this purpose we shall find it more convenient to use a cryophorus of this shape (fig. 4.), as its elongated bulb passes easily through a brass plate which closes the top of the receiver. If we now exhaust the receiver quickly, you will see, in less than a minute, the water freeze in the other bulb, out of the receiver.

Emily. The bulb already looks quite dim, and small drops of water are condensing on its surface.

Caroline. And now crystals of ice shoot all over the water. This is, indeed, a very curious experiment!

Mrs. B. You will see, some other day, that, by a similar method, even quicksilver may be frozen.—But we cannot at present indulge in any further digression.

Having advanced so far on the subject of heat, I may now give you an account of the calorimeter, an instrument invented by Lavoisier, upon the principles just explained, for the purpose of estimating the specific heat of bodies. It consists of a vessel, the inner surface of which is lined with ice, so as to form a sort of hollow globe of ice, in the midst of which the body, whose specific heat is to be ascertained, is placed. The ice absorbs caloric from this body, till it has brought it down to the freezing point; this caloric converts into water a certain portion of the ice which runs out through an aperture at the bottom of the machine; and the quantity of ice changed to water is a test of the quantity of caloric which the body has given out in descending from a certain temperature to the freezing point.

Caroline. In this apparatus, I suppose, the milk, chalk, and lead, would melt different quantities of ice, in proportion to their different capacities for caloric?

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* This mode of making the experiment was proposed, and the particulars detailed, by Dr. Marcet, in the 34th vol. of Nicholson's Journal, p. 119.

Mrs. B. Certainly: and thence we are able to ascertain, with precision, their respective capacities for heat. But the calorimeter affords us no more idea of the absolute quantity of heat contained in a body, than the thermometer; for though by means of it we extricate both the free and combined caloric, yet we extricate them only to a certain degree, which is the freezing point; and we know not how much they contain of either below that point.

Emily. According to the theory of latent heat, it appears to me that the weather should be warm when it freezes, and cold in a thaw: for latent heat is liberated from every substance that it freezes, and such a large supply of heat must warm the atmosphere; whilst, during a thaw, that very quantity of free heat must be taken from the atmosphere, and return to a latent state in the bodies which it thaws.

Mrs. B. Your observation is very natural; but consider that in a frost the atmosphere is so much colder than the earth, that all the caloric which it takes from the freezing bodies is insufficient to raise its temperature above the freezing point; otherwise the frost must cease. But if the quantity of latent heat extricated does not destroy the frost, it serves to moderate the suddenness of the change of temperature of the atmosphere, at the commencement both of frost, and of a thaw. In the first instance, its extrication diminishes the severity of the cold; and, in the latter, its absorption moderates the warmth occasioned by a thaw; it even sometimes produces a discernable chill, at the breaking up of a frost.

Caroline. But what are the general causes that produce those sudden changes in the weather, especially from hot to cold, which we often experience?

Mrs. B. This question would lead us into meteorological discussions, to which I am by no means competent. One circumstance, however, we can easily understand. When the air has passed over cold countries, it will probably arrive here at a temperature much below our own, and then it must absorb heat from every object it meets with, which will produce a general fall of temperature.

Caroline. But pray, now that we know so much of the effects of heat, will you inform us whether it is really a distinct body, or, as I have heard, a peculiar kind of motion produced in bodies?

Mrs. B. As I before told you, there is yet much uncertainty as to the nature of these subtle agents. But I am inclined to consider heat not as a mere motion, but as a separate substance. Late experiments too appear to make it a compound body, consisting of the two electricities, and in our next conversation I shall inform you of the principal facts on which that opinion is founded.

CONVERSATION V.

ON THE CHEMICAL AGENCIES OF ELECTRICITY.*

Mrs. B. BEFORE we proceed further it will be necessary to give you some account of certain properties of electricity, which have of late years been discovered to have an essential connection with the phenomena of chemistry.

Caroline. It is ELECTRICITY, if I recollect right, which comes next in our list of simple substances?

Mrs. B. I have placed electricity in that list, rather from the necessity of classing it somewhere, than from any conviction that it has a right to that situation, for we are as yet so ignorant of its intimate nature, that we are unable to determine, not only whether it is simple or compound, but whether it is in fact a material agent; or, as Sir H. Davy has hinted, whether it may not be merely a property inherent in matter. As, however, it is necessary to adopt some hypothesis for the explanation of the discoveries which this agent has enabled us to make, I have chosen the opinion, at present most prevalent, which supposes the existence of two kinds of electricity, distinguished by the names of *positive* and *negative* electricity.

Caroline. Well, I must confess, I do not feel nearly so interested in a science in which so much uncertainty prevails, as in those which rest upon established principles; I never was fond of electricity, because, however beautiful and curious the phenomena it exhibits may be, the theories, by which they were explained, appeared to me so various, so obscure and inadequate, that I always remained dissatisfied. I was in hopes that the new discoveries in electricity had thrown so great a light on the subject, that every thing respecting it would now have been clearly explained.

Mrs. B. That is a point which we are yet far from having attained. But, in spite of the imperfection of our theories, you will be amply repaid by the importance and novelty of the subject. The number of new facts which have already been ascertained, and the immense prospect of discovery which has lately been opened to us, will, I hope, ultimately lead to a perfect elucidation of this branch of natural science; but at present you must be contented with studying the effects, and in some degree explaining the phenomena, without aspiring to a precise knowledge of the remote cause of electricity.

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* The electricity extricated by the metals is commonly called *Galvanism*. C.

You have already obtained some notions of electricity: in our present conversation, therefore, I shall confine myself to that part of the science which is of late discovery, and is more particularly connected with chemistry.

It was a trifling and accidental circumstance which first gave rise to this new branch of physical science. Galvani, a professor of natural philosophy at Bologna, being engaged (about twenty years ago) in some experiments on muscular irritability, observed, that when a piece of metal was laid on the nerve of a frog, recently dead, whilst the limb supplied by that nerve rested upon some other metal, the limb suddenly moved, on a communication being made between the two pieces of metal.

Emily. How is this communication made?

Mrs. B. Either by bringing the two metals into contact, or by connecting them by means of a metallic conductor. But without subjecting a frog to any cruel experiments, I can easily make you sensible of this kind of electric action. Here is a piece of zinc, (one of the metals I mentioned in the list of elementary bodies)—put it *under* your tongue, and this piece of silver *upon* your tongue, and let both the metals project a little beyond the tip of the tongue—very well—now make the projecting parts of the metals touch each other, and you will instantly perceive a peculiar sensation.

Emily. Indeed I did, a singular taste, and I think, a degree of heat; but I can hardly describe it.

Mrs. B. The action of these two pieces of metal on the tongue is, I believe, precisely similar to that made on the nerve of a frog. I shall not detain you by a detailed account of the theory by which Galvani attempted to explain this fact, as it was soon overturned by subseqnent experiments, which proved that *Galvanism* (the name this new power had obtained) was nothing more than electricity. Galvani supposed that the virtue of this new agent resided in the nerves of the frog, but Volta, who prosecuted this subject with much greater success, showed that the phenomena did not depend on the organs of the frog, but upon the electrical agency of the metals, which is excited by the moisture of the animal, the organs of the frog being only a delicate test of the presence of electric influence.

Caroline. I suppose, then, the saliva of the mouth answers the same purpose as the moisture of the frog, in exciting the electricity of the pieces of silver and zinc with which Emily tried the experiment on her tongue.

Mrs. B. Precisely. It does not appear, however, necessary that the fluid used for this purpose should be of an animal nature. Water, and acids very much diluted by water, are found to be the most effectual in promoting the developement of electricity in metals; and, accordingly, the original apparatus which Volta first constructed for this purpose, consisted of a pile or succession of plates of zinc and copper, each pair of which was connected by pieces of cloth or paper impregnated with water; and this instrument, from its original inconvenient structure and limited strength, has gradually arrived at this present state of power and improvement, such as is exhibited in the Voltaic battery. In this apparatus, a specimen of which you see before you (Plate VI. fig. 1.,) the plates of zinc and copper are soldered together in pairs, each pair being placed at regular distances in wooden troughs and the interstices being filled with fluid.

Caroline. Though you will not allow us to inquire into the precise cause of electricity, may we not ask in what manner the fluid acts on the metals so as to produce it?

Mrs. B. The action of the fluid on the metals, whether water or acid be used, is entirely of a chemical nature. But whether electricity is excited by this chemical action, or whether it is produced by the contact of the two metals, is a point upon which philosophers do not yet perfectly agree.

Emily. But can the mere contact of two metals, without any intervening fluid, produce electricity?

Mrs. B. Yes, if they are afterwards separated. It is an established fact, that when two metals are put in contact, and afterwards separated, that which has the strongest attraction for oxygen exhibits signs of positive, the other of negative electricity.

Caroline. It seems then but reasonoble to infer that the power of the Voltaic battery should arise from the contact of the plates of zinc and copper.

Mrs. B. It is upon this principle that Volta and Sir H. Davy explain the phenomena of the pile; but notwithstanding these two great authorities, many philosophers entertain doubts on the truth of this theory. The chief difficulty which occurs in explaining the phenomena of the Voltaic battery on this principle, is, that two such plates show no signs of different states of electricity whilst in contact, but only on being separated after contact. Now in the Voltaic battery, those plates that are

PLATE. VI.

Fig. 1.
Voltaic Battery

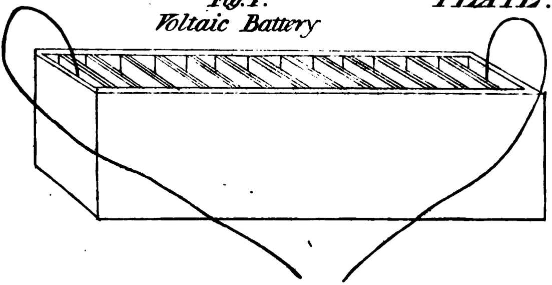

Fig. 2.

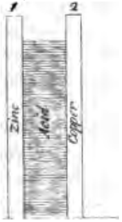

Fig. 4.

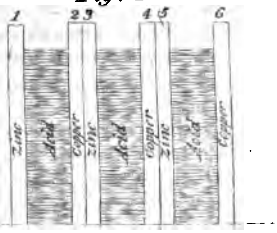

Fig. 3.
Electrical Machine.

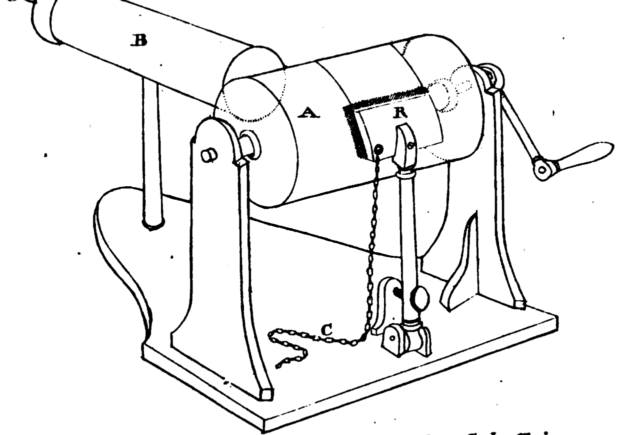

Fig. 3. A the Cylinder.—B the Conductor.—R the Ruber.—C the Chain.
Fig. 1. 2 & 4. Voltaic Batteries.

in contact always continue so, being soldered together: and they cannot therefore receive a succession of charges. Besides, if we consider the mere disturbance of the balance of electricity by the contact of the plates, as the sole cause of the production of Voltaic electricity, it remains to be explained how this disturbed balance becomes an inexhaustible source of electrical energy, capable of pouring forth a constant and copious supply of electrical fluid, though without any means of replenishing itself from other sources. This subject, it must be owned, is involved in too much obscurity to enable us to speak very decidedly in favour of any theory. But, in order to avoid perplexing you with different explanations, I shall confine myself to one which appears to me to be least encumbered with difficulties, and most likely to accord with truth.*

This theory supposes the electricity to be excited by the chemical action of the acid on the zinc; but you are yet such novices in chemistry, that I think it will be necessary to give you some previous explanation of the nature of this action.

All metals have a strong attraction for oxygen, and this element is found in great abundance both in water and in acids. The action of the diluted acid on the zinc consists therefore in its oxygen combining with it, and dissolving its surface.

Caroline. In the same manner I suppose as we saw an acid dissolve copper?

Mrs. B Yes; but in the Voltaic battery the diluted acid is not strong enough to produce so complete an effect; it acts only on the surface of the zinc, to which it yields its oxygen, forming upon it a film or crust, which is a compound of the oxygen and the metal.

Emily. Since there is so strong a chemical attraction between oxygen and metals, I suppose they are naturally in different states of electricity?

Mrs. B. Yes; it appears that all metals are united with the positive, and that oxygen is the grand source of the negative electricity.

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* This mode of explaining the phenomena of the Voltaic pile is called the *chemical theory* of electricity, because it ascribes the cause of these phenomena to certain chemical changes which take place during their appearance. The mode which is here sketched was long since suggested by Dr. Bostock, who has lately (1818) published "An Account of the History and present State of Galvanism;" which contains a fuller and more complete statement of his opinions, and those of other writers on the subject, than any of his former papers.

Caroline. Does not then the acid act on the plates of copper, as well as on those of zinc?*

Mrs. B. No; for though copper has an affinity for oxygen, it is less strong than that of zinc; and therefore the energy of the acid is only exerted upon the zinc.

It will be best, I believe, in order to render the action of the Voltaic battery more intelligible, to confine our attention at first to the effect produced on two plates only. (Plate VI. fig. 2.)

If a plate of zinc be placed opposite to one of copper, or any other metal less attractive of oxygen, and the space between them (suppose of half an inch in thickness,) be filled with an acid or any fluid capable of oxydating the zinc, the oxydated surface will have its capacity for electricity diminished, so that a quantity of electricity will be evolved from that surface. This electricity will be received by the contiguous fluid, by which it will be transmitted to the opposite metallic surface, the copper, which is not oxydated, and is therefore disposed to receive it; so that the copper plate will thus become positive, whilst the zinc plate will be in the negative state.

This evolution of electrical fluid however will be very limited; for as these two plates admit of but very little accumulation of electricity, and are supposed to have no communication with other bodies, the action of the acid, and further developement of electricity, will be immediately stopped.

Emily. This action, I suppose, can no more continue than that of a common electrical machine, which is not allowed to communicate with other bodies?

Mrs. B. Precisely; the common electrical machine, when excited by the friction of the rubber, gives out both the positive and negative electricities.—(Plate VI. Fig. 3.) The positive, by the rotation of the glass cylinder, is conveyed into the conductor, whilst the negative goes into the rubber. But, unless there is a communication made between the rubber and the ground, a very inconsiderable quantity of electricity can be excited; for the rubber, like the plates of the battery, has too small a capacity to admit of an accumulation of electricity. Unless therefore the electricity can pass out of the rubber, it will not continue to go into it, and consequently no additional accumulation will take place. Now as one kind of electricity cannot be given out without the other, the developement of the positive electricity is stopped as well as that of the negative, and the conductor therefore cannot receive a succession of charges.

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* The acid acts upon the copper, but not so strongly as on the zinc. Any two metals, one of which has a stronger attraction for oxygen than the other, will form the galvanic series. C.

Caroline. But does not the conductor, as well as the rubber, require a communication with the earth, in order to get rid of its electricity?

Mrs. B. No; for it is susceptible of receiving and containing a considerable quantity of electricity, as it is much larger than the rubber, and therefore has a greater capacity; and this continued accumulation of electricity in the conductor is what is called a charge.

Emily. But when an electrical machine is furnished with two conductors to receive the two electricities, I suppose no communication with the earth is required?

Mrs. B. Certainly not, until the two are fully charged; for the two conductors will receive equal quantities of electricity.

Caroline. I thought the use of the chain had been to convey the electricity *from* the ground into the machine?

Mrs. B. That was the idea of Dr. Franklin, who supposed that there was but one kind of electricity, and who, by the terms positive and negative (which he first introduced,) meant only different quantities of the same kind of electricity.* The chain was in that case supposed to convey electricity *from* the ground through the rubber into the conductor. But as we have adopted the hypothesis of two electrics, we must consider the chain as a vehicle to conduct the negative electricity into the earth.

Emily. And are both kinds produced whenever electricity is excited?

Mrs. B. Yes, invariably. If you rub a tube of glass with a woolen cloth, the glass becomes positive, and the cloth negative.† If, on the contrary, you excite a stick of sealing-wax by the same means, it is the rubber which becomes positive, and the wax negative.

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* The idea of Dr. Franklin, was, that the positive state consisted in the presence, or accumulation of the electric fluid, and that the negative was merely its absence or diminution. Hence the terms used by him to indicate these states were *positive* and *negative.* In this chapter Mrs. B. has used these terms of the American Philosopher improperly, for *plus* and *minus* were never meant to signify two sorts of electricity, but only its *presence,* or *absence.* Where authors have adopted Dufay's theory, of two electricities, they have used the, terms, *vitreous* and *resinous.* C.

† Most probably, because the glass takes the electric fluid from the cloth. Indeed we conceive there is about the same reason for believing that the negative state, is the absence of the electric fluid, as there is for believing that cold is the absence of heat. C.

But with regard to the Voltaic battery, in order that the acid may act freely on the zinc, and the two electricities be given out without interruption, some method must be devised, by which the plates may part with their electricities as fast as they receive them.—Can you think of any means by which this might be effected?

Emily. Would not two chains or wires, suspended from either plate to the ground, conduct the electricities into the earth, and thus answer the purpose?

Mrs. B. It would answer the purpose of carrying off the electricity, I admit; but recollect, that though it is necessary to find a vent for the electricity, yet we must not lose it, since it is the power which we are endeavouring to obtain. Instead, therefore, of conducting it into the ground, let us make the wires, from either plate, meet: the two electricities will thus be brought together, and will combine and neutralize each other; and as long as this communication continues, the two plates having a vent for their respective electricities, the action of the acid will go on freely and uninterruptedly.

Emily. That is very clear, so far as two plates only are concerned; but I cannot say I understand how the energy of the succession of plates, or rather pairs of plates, of which the Galvanic trough is composed, is propagated and accumulated throughout a battery?

Mrs. B. In order to show you how the intensity of the electricity is increased by increasing the number of plates, we will examine the action of four plates; if you understand these, you will readily comprehend that of any number whatever. In this figure (Plate VI. fig. 4.,) you will observe that the two central plates are united; they are soldered together, (as we observed in describing the Voltaic trough,) so as to form but one plate which offers two different surfaces, the one of copper, the other of zinc.

Now you recollect that, in explaining the action of two plates, we supposed that a quantity of electricity was evolved from the surface of the first zinc plate, in consequence of the action of the acid, and was conveyed by the interposed fluid to the copper plate, No. 2, which thus became positive. This copper plate communicates its electricity to the contiguous zinc plate, No. 3, in which, consequently, some accumulation of electricity takes place. When, therefore, the fluid in the next cell acts upon the zinc plate, electricity is extricated from it in larger quantity, and in a more concentrated form than before. This concentrated electricity is again conveyed by the fluid to the next pair of plates, No. 4 and 5, when it is farther increased by the action of the fluid in the third cell, and so on, to any number of plates of which the battery may consist; so that the electrical energy will continue to accumulate in proportion to the number of double plates, the first zinc plate of the series being the most negative, and the last copper plate the most positive.

Caroline. But does the battery become more and more strongly charged, merely by being allowed to stand undisturbed?

Mrs. B. No, for the action will soon stop, as was explained before, unless a vent be given to the accumulated electricities. This is easily done, however, by establishing a communication by means of the wires (Fig. 1.,) between the two ends of the battery: these being brought into contact, the two electricities meet and neutralize each other, producing the shock and other effects of electricity; and the action goes on with renewed energy, being no longer obstructed by the accumulation of the two electricities which impeded its progress.

Emily. Is it the union of the two electricities which produces the electric spark?

Mrs. B. Yes; and it is, I believe, this circumstance which gave rise to Sir H. Davy's opinion that caloric may be a compound of the two electricities.

Caroline. Yet surely caloric is very different from the electrical spark?

Mrs. B. The difference may consist probably only in intensity; for the heat of the electric spark is considerably more intense, though confined to a very minute spot, than any heat we can produce by other means.

Emily. Is it quite certain that the electricity of the Voltaic battery is precisely of the same nature as that of the common electrical machine?

Mrs. B. Undoubtedly; the shock given to the human body, the spark, the circumstance of the same substances which are conductors of the one being also conductors of the other, and of those bodies, such as glass and sealing-wax, which are non-conductors of the one, being also non-conductors of the other, are striking proofs of it. Besides, Sir H. Davy has shewn in his Lectures, that a Leyden jar, and a common electric battery, can be charged with electricity obtained from a Voltaic battery, the effect produced being perfectly similar to that obtained by a common machine.

Dr. Wollaston has likewise proved that similar chemical decompositions are effected by the electric machine and by the

Voltaic battery; and has made other experiments which render it highly probable, that the origin of both electricities is essentially the same, as they show that the rubber of the common electrical machine, like the zinc in the Voltaic battery, produces the two electricities by combining with oxygen.

Caroline. But I do not see whence the rubber obtains oxygen, for there is neither acid nor water used in the common machine, and I always understood that the electricity was excited by the friction.

Mrs. B. It appears that by friction the rubber obtains oxygen from the atmosphere, which is partly composed of that element. The oxygen combines with the amalgam of the rubber, which is of a metallic nature, much in the same way as the oxygen of the acid combines with the zinc in the Voltaic battery, and it is thus that the two electricities are disengaged.

Caroline. But, if the electricities of both machines are similar, why not use the common machine for chemical decomposition?

Mrs. B. Though its effects are similar to those of the Voltaic battery, they are incomparably weaker. Indeed Dr. Wollaston, in using it for chemical decompositions, was obliged to act upon the most minute quantities of matter, and though the result was satisfactory in proving the similarity of its effects to those of the Voltaic battery, these effects were too small in extent to be in any considerable degree applicable to chemical decomposition.

Caroline. How terrible, then, the shock must be from a Voltaic battery, since it is so much more powerful than an electrical machine!

Mrs. B. It is not nearly so formidable as you think; at least it is by no means proportional to the chemical effect. The great superiority of the Voltaic battery consists in the large *quantity* of electricity that passes; but in regard to the *rapidity* or *intensity* of the charge, it is greatly surpassed by the common electrical machine. It would seem that the shock or sensation depends chiefly upon the intensity; whilst, on the contrary, for chemical purposes, it is quantity which is required. In the Voltaic battery, the electricity, though copious, is so weak as not to be able to force its way through the fluid which separates the plates, whilst that of a common machine will pass through any space of water.

Caroline. Would not it be possible to increase the intensity of the Voltaic battery till it should equal that of the common machine?

Mrs. B. It can actually be increased till it imitates a weak electrical machine, so as to produce a visible spark when accumulated in a Leyden jar. But it can never be raised sufficiently to pass through any considerable extent of air, because of the ready communication through the fluids employed.

By increasing the number of plates of a battery, you increase its *intensity*, whilst, by enlarging the dimensions of the plates, you augment its *quantity*; and, as the superiority of the battery over the common machine consists entirely in the quantity of electricity produced, it was at first supposed that it was the size, rather than the number of plates that was essential to the augmentation of power. It was, however, found upon trial, that the quantity of electricity produced by the Voltaic battery, even when of a very moderate size, was sufficiently copious, and that the chief advantage in this apparatus was obtained by increasing the intensity, which, however, still falls very short of that of the common machine.

I should not omit to mention, that a very splendid, and, at the same time, most powerful battery, was, a few years ago, constructed under the direction of Sir H. Davy, which he repeatedly exhibited in his course of electro-chemical lectures. It consists of two thousand double plates of zinc and copper, of six square inches in dimensions, arranged in troughs of Wedgwood-ware, each of which contains twenty of these plates. The troughs are furnished with a contrivance for lifting the plates out of them in a very convenient and expeditious manner.*

Caroline. Well, now that we understand the nature of the action of the Voltaic battery, I long to hear an account of the discoveries to which it has given rise.

Mrs. B. You must restrain your impatience, my dear, for I cannot with any propriety introduce the subject of these discoveries till we come to them in the regular course of our studies. But, as almost every substance in nature has already been exposed to the influence of the Voltaic battery, we shall very soon have occasion to notice its effects.

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* A model of this mode of construction is exhibited in PLATE XIII. Fig. 1.

Note. In consequence of the discoveries of Prof. Hare, of Philadelphia, the present theory of galvanism must probably undergo a radical change. This gentleman has invented a new method of extricating the Voltaic influence, by so connecting the plates, that in effect only two great surfaces of the metals are presented to each other. By this arrangement, the galvanic action on different substances, has presented some new phenomena. The calorific principle is immensely increased, while the electric shock is hardly to be perceived. Prof. Hare has named this new apparatus *calorimotor*, or heat mover.

CONVERSATION VI.

ON OXYGEN AND NITROGEN.

Mrs. B. To-DAY we shall examine the chemical properties of the ATMOSPHERE.

Caroline. I thought that we were first to learn the nature of OXYGEN, which comes next in our table of simple bodies?

Mrs. B. And so you shall; the atmosphere being composed of two principles, OXYGEN and NITROGEN, we shall proceed to analyse it, and consider its component parts separately.

Emily. I always thought that the atmosphere had been a very complicated fluid, composed of all the variety of exhalations from the earth.

Mrs. B. Such substances may be considered rather as heterogeneous and accidental, than as forming any of its component parts; and the proportion they bear to the whole mass is quite inconsiderable.

ATMOSPHERICAL AIR it composed of two gases, known by the names of OXYGEN GAS and NITROGEN OR AZOTIC GAS.

Emily. Pray what is a gas?*

Mrs. B. The name of gas is given to any fluid capable of existing constantly in an aëriform state, under the pressure and at the temperature of the atmosphere.

Caroline. Is not water, or any other substance, when evaporated by heat, called gas?

Mrs. B. No, my dear; vapour is, indeed, an elastic fluid, and bears a strong resemblance to a gas; there are, however, several points in which they essentially differ, and by which you may always distinguish them. Steam, or vapour, owes its elasticity merely to a high temperature, which is equal to that of boiling water. And it differs from boiling water only by being united with more caloric, which, as we before explained, is in a latent state. When steam is cooled, it instantly returns to the form of water; but air, or gas, has never yet been rendered liquid or solid by any degree of cold.

The new views which he has been induced to offer, seem to be confirmed by the action of the colorimotor, viz. that galvanism is a compound of electricity and caloric. This theory, it is obvious, will set aside many of the principles laid down in the foregoing chapter. An account of this theory, with a description of the calorimotor, is published in Silliman's Journal, with Observations by the Editor; also in Hare's edition of Henry's Chemistry. C.

* All kinds of air differing from the atmosphere, are called by this name. C.

Emily. But does not gas, as well as vapour, owe its elasticity to caloric?

Mrs. B. It was the prevailing opinion; and the difference between gas and vapour was thought to depend on the different manner in which caloric was united with the bases of these two kinds of elastic fluids. In vapour it was considered as in a latent state; in gas, it was said to be chemically combined. But the late researches of Sir H. Davy have given rise to a new theory respecting gases; and there is now reason to believe that these bodies owe their permanently elastic state, not solely to caloric, but likewise to the prevalence of either the one or the other of the two electricities.*

Emily. When you speak, then, of the simple bodies, oxygen and nitrogen, you mean to express those substances which are the basis of the two gases?

Mrs. B. Yes, in strict propriety, for they can properly be called gases only when brought to an aëriform state.

Caroline. In what proportions are they combined in the atmosphere?

Mrs. B. The oxygen gas constitutes a little more than one-fifth, and the nitrogen gas a little less than four-fifths.† When separated, they are found to possess qualities totally different from each other. For oxygen gas is essential both to respiration and combustion, while neither of these processes can be performed in nitrogen gas.

Caroline. But if nitrogen gas is unfit for respiration, how does it happen that the large proportion of it which enters into the composition of the atmosphere is not a great impediment to breathing?

Mrs. B. We should breathe more freely than our lungs could bear, if we respired oxygen gas alone. The nitrogen is no impediment to respiration, and probably, on the contrary, answers some useful purpose, though we do not know in what manner it acts in that process.

Emily. And by what means can the two gases, which compose the atmospheric air be separated?

Mrs. B. There are many ways of analysing the atmosphere: the two gases may be separated first by combustion.

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* This wants further proof. The former theory, that the gases owe their elasticity to caloric combined with their bases. we think accounts equally well for this property, and at the same time is more simple, and better proved. C.

† In 100 parts of atmospheric air, there is 21 of oxygen and 79 of nitrogen. C.

Emily. You surprise me! how is it possible that combustion should separate them?

Mrs. B. I should previously remind you that oxygen is supposed to be the only simple body naturally combined with negative electricity. In all the other elements the positive electricity prevails, and they have consequently, all of them, an attraction for oxygen.* †

Caroline. Oxygen the only negatively electrified body! that surprises me extremely; how then are the combinations of the other bodies performed, if, according to your explanation of chemical attraction, bodies are supposed only to combine in virtue of their opposite states of electricity?

Mrs. B. Observe that I said, that oxygen was the only *simple* body, naturally negative. Compound bodies, in which oxygen prevails over the other component parts, are also negative, but their negative energy is greater or less in proportion as the oxygen predominates. Those compounds into which oxygen enters in less proportion than the other constituents, are positive, but their positive energy is diminished in proportion to the quantity of oxygen which enters into their composition.

All bodies, therefore, that are not already combined with oxygen, will attract it, and, under certain circumstances, will absorb it from the atmosphere, in which case the nitrogen gas will remain alone, and may thus be obtained in its separate state.

Caroline. I do not understand how a gas can be absorbed?

Mrs. B. It is only the oxygen, or basis of the gas, which is absorbed; and the two electricities escaping, that is to say, the negative from the oxygen, the positive from the burning body, unite and produce caloric.

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* If chlorine or oxymuriatic gas be a simple body, according to Sir H. Davy's view of the subject, it must be considered as an exception to this statement; but this subject cannot be discussed till the properties and nature of chlorine come under examination.

† The hypothesis that combustion, as well as chemical affinity are electrical phenomena, was first proposed by Berzelius, of Stockholm. The theory is shortly this. In all cases, where the particles of bodies, have a chemical attraction for each other, they are in opposite states of electricity, and the force of their union is in proportion to the intensity of these electrical states, since it is this which forces them to unite. Thus the particles of an acid, and an alkali unite. because one is strongly negative, and the other strongly positive. In cases of combustion, these different states are still more intense, oxygen always being in the negative state, and the combustible in the positive, and when a union takes place, heat and light is the consequence. This theory is not well proved, nor generally adopted. C.

Emily. And what becomes of this caloric?

Mrs. B. We shall make this piece of dry wood attract oxygen from the atmosphere, and you will see what becomes of the caloric.

Caroline. You are joking, Mrs. B—; you do not mean to decompose the atmosphere with a piece of dry stick?

Mrs. B. Not the whole body of the atmosphere, certainly; but if we can make this piece of wood attract any quantity of oxygen from it, a proportional quantity of atmospherical air will be decomposed.

Caroline. If wood has so strong an attraction for oxygen, why does it not decompose the atmosphere spontaneously?

Mrs. B. It is found by experience, that an elevation of temperature is required for the commencement of the union of the oxygen and the wood.

This elevation of temperature was formerly thought to be necessary, in order to diminish the cohesive attraction of the wood, and enable the oxygen to penetrate and combine with it more readily. But since the introduction of the new theory of chemical combination, another cause has been assigned, and it is now supposed that the high temperature, by exalting the electrical energies of bodies, and consequently their force of attraction, facilitates their combination.

Emily. If it is true, that caloric is composed of the two electricities, an elevation of temperature must necessarily augment the electric energies of bodies.

Mrs. B. I doubt whether that would be a necessary consequence; for, admitting this composition of caloric, it is only by its being decomposed that electricity can be produced. Sir H. Davy, however, in his numerous experiments, has found it to be an almost invariable rule that the electrical energies of bodies are increased by elevation of temperature.

What means then shall we employ to raise the temperature of the wood, so as to enable it to attract oxygen from the atmosphere?

Caroline. Holding it near the fire, I should think, would answer the purpose.

Mrs. B. It may, provided you hold it sufficiently close to the fire; for a very considerable elevation of temperature is required.

Caroline. It has actually taken fire, and yet I did not let it touch the coals, but I held it so very close that I suppose it caught fire merely from the intensity of the heat.

Mrs. B. Or you might say, in other words, that the caloric which the wood imbibed, so much elevated its temperature, and exalted its electric energy, as to enable it to attract oxygen very rapidly from the atmosphere.

Emily. Does the wood absorb oxygen while it is burning?

Mrs. B. Yes, and the heat and light are produced by the union of the two electricities which are set at liberty, in consequence of the oxygen combining with the wood.

Caroline. You astonish me! the heat of a burning body proceeds then as much from the atmospere as from the body itself?

Mrs. B. It was supposed that the caloric, given out during combustion, proceeded entirely, or nearly so, from the decomposition of the oxygen gas; but, according to Sir H. Davy's new view of the subject, both the oxygen gas, and the combustible body, concur in supplying the heat and light, by the union of their opposite electricities.

Emily. I have not yet met with any thing in chemistry that has surprised or delighted me so much as this explanation of combustion. I was at first wondering what connection there could be between the affinity of a body for oxygen and its combustibility; but I think I understand it now perfectly.

Mrs. B. Combustion then, you see, is nothing more than the rapid combination of a body with oxygen, attended by the disengagement of light and heat.

Emily. But are there no combustible bodies whose attraction for oxygen is so strong, that they will combine with it, without the application of heat?

Caroline. That cannot be; otherwise we should see bodies burning spontaneously.

Mrs. B. But there are some instances of this kind, such as phosphorus, potassium, and some compound bodies, which I shall hereafter make you acquainted with. These bodies, however, are prepared by art, for in general, all the combustions that could occur spontaneously, at the temperature of the atmosphere, have already taken place; therefore new combustions cannot happen without the temperature of the body being raised. Some bodies, however, will burn at a much lower temperature than others.

Caroline. But the common way of burning a body is not merely to approach it to one already on fire, but rather to put the one in actual contact with the other, as when I burn this piece of paper by holding it in the flame of the fire.

Mrs. B. The closer it is in contact with the source of caloric, the sooner will its temperature be raised to the degree necessary for it to burn. If you hold it near the fire, the same effect will

PLATE VII.

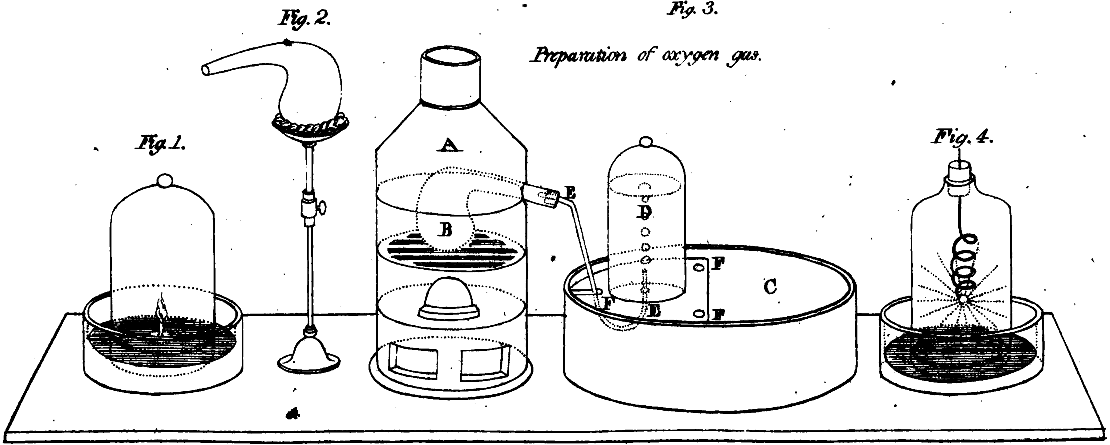

Fig. 1. Combustion of a taper under a receiver._Fig. 2. A Retort on a stand._Fig. 3. A Furnace. B Earthen Retort in the furnace. C Water bath. D Receiver. EE Tube conveying the gas from the Retort through the water into the Receiver. FFF. Shelf perforated on which the Receiver stands. Fig. 4. Combustion of iron wire in oxygen gas.

be produced; but more time will be required, as you found to be the case with the piece of stick.

Emily. But why is it not necessary to continue applying caloric throughout the process of combustion, in order to keep up the electric energy of the wood, which is required to enable it to combine with the oxygen?

Mrs. B. The caloric which is gradually produced by the two electricities during combustion, keeps up the temperature of the burning body, so that when once combustion has begun, no further application of caloric is required.

Caroline. Since I have learnt this wonderful theory of combustion, I cannot take my eyes from the fire; and I can scarcely conceive that the heat and light, which I always supposed to proceed entirely from the coals, are really produced as much by the atmosphere.

Emily. When you blow the fire, you increase the combustion, I suppose, by supplying the coals with a greater quantity of oxygen gas?

Mrs. B. Certainly; but of course no blowiug will produce combustion, unless the temperature of the coals be first raised. A single spark, however, is sometimes sufficient to produce that effect; for, as I said before, when once combustion has commenced, the caloric disengaged is sufficient to elevate the temperature of the rest of the body, provided that there be a free access of oxygen. It however sometimes happens that if a fire be ill made, it will be extinguished before all the fuel is consumed, from the very circumstance of the combustion being so slow that the caloric disengaged is insufficient to keep up the temperature of the fuel. You must recollect that there are three things required in order to produce combustion; a combustible body, oxygen, and a temperature at which the one will combine with the other.

Emily. You said that combustion was one method of decomposing the atmosphere, and obtaining the nitrogen gas in its simple state; but how do you secure this gas, and prevent it from mixing with the rest of the atmosphere?

Mrs. B. It is necessary for this purpose to burn the body within a close vessel, which is easily done.—We shall introduce a small lighted taper, (Plate VII. Fig. 1.) under this glass receiver, which stands in a bason over water, to prevent all communication with the external air.*

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* To make a taper, melt some bees wax, and dip into it a strip of cotton cloth about an inch wide, and before it is cold, twist it pretty hard. Cotton wick does better than the cloth. A quart tumbler makes

Caroline. How dim the light burns already!—It is now extinguished.

Mrs. B. Can you tell us why it is extinguished?

Caroline. Let me consider.—The receiver was full of atmospherical air; the taper, in burning within it, must have combined with the oxygen contained in that air, and the caloric that was disengaged produced the light of the taper. But when the whole of the oxygen was absorbed, the whole of its electricity was disengaged; consequently no more caloric could be produced, the taper ceased to burn, and the flame was extinguished.

Mrs. B. Your explanation is perfectly correct.

Emily. The two constituents of the oxygen gas being thus disposed of, what remains under the receiver must be pure nitrogen gas?

Mrs. B. There are some circumstances which prevent the nitrogen gas, thus obtained, from being perfectly pure; but we may easily try whether the oxygen has disappeared, by putting another lighted taper under it.—You see how instantaneously the flame is extinguished, for want of oxygen to supply the negative electricity required for the formation of caloric; and were you to put an animal under the receiver, it would immediately be suffocated. But that is an experiment which I do not think your curiosity will tempt you to try.

Emily. Certainly not.—But look Mrs. B., the receiver is full of a thick white smoke. Is that nitrogen gas?

Mrs. B. No, my dear; nitrogen gas is perfectly transparent and invisible, like common air. This cloudiness proceeds from a variety of exhalations, which arise from the burning taper, the nature of which you cannot yet understand.

Caroline. The water within the receiver has now risen a little above its level in the bason. What is the reason of this?

Mrs. B. With a moment's reflection, I dare say, you would have explained it yourself. The water rises in consequence of the oxygen gas within it having been destroyed, or rather decomposed by the combustion of the taper.

Caroline. Then why did not the water rise immediately when the oxygen gas was destroyed?

Mrs. B. Because the heat of the taper, whilst burning, produced a dilatation of the air in the vessel, which at first counteracted this effect.

Another means of decomposing the atmosphere is the *oxyge-*

a good receiver. Two or three inches of the taper can be fastened to a piece of wire, bent so that it will stand up. Thus the experiment is easily made. C.

nation of certain metals. This process is very analogous to combustion; it is, indeed, only a more general term to express the combination of a body with oxygen.

Caroline. In what respect, then, does it differ from combustion?

Mrs. B. The combination of oxygen in combustion is always accompanied by a disengagement of light and heat; whilst this circumstance is not a necessary consequence of simple oxygenation.

Caroline. But how can a body absorb oxygen without the combination of the two electricities which produce caloric?

Mrs. B. Oxygen does not always present itself in a gaseous form; it is a constituent part of a vast number of bodies, both solid and liquid, in which it exists in a state of greater density than in the atmosphere; and from these bodies it may be obtained without much disengagement of caloric. It may likewise, in some cases, be absorbed from the atmosphere without any sensible production of light and heat; for, if the process be slow, the caloric is disengaged in such small quantities, and so gradually, that it is not capable of producing either light or heat. In this case the absorption of oxygen is called *oxygenation* or *oxydation*, instead of *combustion*, as the production of sensible light and heat is essential to the latter.

Emily. I wonder that metals can unite with oxygen; for, as they are so dense, their attraction of aggregation must be very great; and I should have thought that oxygen could never have penetrated such bodies.

Mrs. B. Their strong attraction for oxygen counterbalances this obstacle. Most metals, however, require to be made red-hot before they are capable of attracting oxygen in any considerable quantity. By this combination they lose most of their metallic properties, and fall into a kind of powder, formerly called *calx*, but now much more properly termed an *oxyd*; thus we have *oxyd of lead*, *oxyd of iron*, &c.*

Emily. And in the Voltaic battery, it is, I suppose, an oxyd of Zinc, that is formed by the union of the oxygen with that metal?

Mrs. B. Yes, it is.

Caroline. The word oxyd, then, simply means a metal combined with oxygen?

Mrs. B. Yes; but the term is not confined to metals, though chiefly applied to them. Any body whatever, that has combined with a certain quantity of oxygen, either by means of oxy-

* *Red lead* and *rust of iron.* C.

dation or combustion, is called an *oxyd*, and is said to be *oxydated* or *oxygenated.*

Emily. Metals, when converted into oxyds, become, I suppose, negative?

Mrs. B. Not in general; because in most oxyds the positive energy of the metal more than counterbalances the native energy of the oxygen with which it combines.

This black powder is an oxyd of manganese, a metal which has so strong an affinity for oxygen, that it attracts that substance from the atmosphere at any known temperature: it is therefore never found in its metallic form, but always in that of an oxyd, in which state, you see, it has very little of the appearance of a metal. It is now heavier than it was before oxydation, in consequence of the additional weight of the oxygen with which it has combined.

Caroline. I am very glad to hear that; for I confess I could not help having some doubts whether oxygen was really a substance, as it is not to be obtained in a simple and palpable state; but its weight is, I think, a decisive proof of its being a real body.

Mrs. B. It is easy to estimate its weight, by separating it from the manganese, and finding how much the latter has lost.

Emily. But if you can take the oxygen from the metal, shall we not then have it in its palpable simple state?

Mrs. B. No; for I can only separate the oxygen from the manganese, by presenting to it some other body, for which it has a greater affinity than for the manganese. Caloric affording the two electricities is decomposed, and one of them uniting with the oxygen, restores it to the aëriform state.

Emily. But you said just now, that manganese would attract oxygen from the atmosphere in which it is combined with the negative electricity; how, therefore, can the oxygen have a superior affinity for that electricity, since it abandons it to combine with the manganese?

Mrs. B. I give you credit for this objection, Emily; and the only answer I can make to it is, that the mutual affinities of metals for oxygen, and of oxygen for electricity, vary at different temperatures; a certain degree of heat, will, therefore, dispose a metal to combine with oxygen, whilst, on the contrary, the former will be compelled to part with the latter, when the temperature is further increased. I have put some oxyd of manganese into a retort,* which is an earthen vessel with a bent neck, such as you see here. (PLATE VII. Fig. 2.) The retort containing the manganese you cannot see, as I have enclosed it in this furnace, where it is now red-hot. But, in order to make you sensible of the escape of the gas, which is itself invisible, I have connected the neck of the retort with this bent tube, the extremity of which is immersed in this vessel of water.—(PLATE VII. Fig. 3.) Do you see the bubbles of air rise through the water?

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* To collect oxygen gas, take an oil flask and having fitted a cork

Caroline. Perfectly. This, then, is pure oxygen gas; what a pity it should be lost! Could you not preserve it?

Mrs. B. We shall collect it in this receiver.—For this purpose, you observe, I first fill it with water, in order to exclude the atmospherical air; and then place it over the bubbles which issue from the retort, so as to make them rise through the water to the upper part of the receiver.

Emily. The bubbles of oxygen gas rise, I suppose, from their specific levity?

Mrs. B. Yes; for though oxygen forms rather a heavy gas, it is light compared to water. You see how it gradually displaces the water from the receiver. It is now full of gas, and I may leave it inverted in water on this shelf, where I can keep the gas as long as I choose, for future experiments. This apparatus (which is indispensable in all experiments in which gasses are concerned) is called a water-bath.*

Caroline. It is a very clever contrivance, indeed; equally simple and useful. How convenient the shelf is for the receiver to rest upon under water, and the holes in it for the gas to pass into the receiver! I long to make some experiments with this apparatus.

Mrs. B. I shall try your skill that way, when you have a little more experience. I am now going to show you an experiment, which proves, in a very striking manner, how essential oxygen is to combustion. You will see that iron itself will burn in this gas, in the most rapid and brilliant manner.

Caroline. Really! I did not know that it was possible to burn iron.

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to it, pierce the cork so as to admit a bent glass tube; (the bending is done over a spirit lamp.) Put into the flask some black oxyd of manganese, and pour on sulphuric acid enough to make it into a paste. Then put in the cork and tube, and having connected the other end of the tube with a receiver, in the tub of water, apply the heat of an argand lamp. C.

* A common large sized wash tub, with a board 4 or 5 inches wide fixed through the middle, and about 6 inches from the top, and filled with water, will answer very well for a great variety of experiments on the gases. C.

Emily. Iron is a simple body, and you know, Caroline, that all simple bodies are naturally positive, and therefore must have an affinity for oxygen.

Mrs. B. Iron will, however, not burn in atmospherical air without a very great elevation of temperature; but it is eminently combustible in pure oxygen gas; and what will surprise you still more, it can be set on fire without any considerable rise of temperature. You see this spiral iron wire*—I fasten it at one end to this cork, which is made to fit an opening at the top of the glass-receiver. (PLATE VII. Fig.4.)

Emily. I see the opening in the receiver; but it is carefully closed by a ground glass-stopper.

Mrs. B. That is in order to prevent the gas from escaping; but I shall take out the stopper, and put in the cork, to which the wire hangs.—Now I mean to burn this wire in the oxygen gas, but I must fix a small piece of lighted tinder to the extremity of it, in order to give the first impulse to combustion; for, however powerful oxygen is in promoting combustion, you must recollect that it cannot take place without some elevation of temperature. I shall now introduce the wire into the receiver, by quickly changing the stoppers.

Caroline. Is there no danger of the gas escaping while you change the stoppers?

Mrs. B. Oxygen gas is a little heavier than atmospherical air, therefore it will not mix with it very rapidly; and, if I do not leave the opening uncovered, we shall not lose any ——

Caroline. Oh, what a brilliant and beautiful flame!

Emily. It is as white and dazzling as the sun!—Now a piece of the melted wire drops to the bottom: I fear it is extinguished; but no, it burns again as bright as ever.

Mrs. B. It will burn till the wire is entirely consumed, provided the oxygen is not first expended: for you know it can burn only while there is oxygen to combine with it.

Caroline. I never saw a more beautiful light. My eyes can hardly bear it! How astonishing to think that all this caloric was contained in the small quantity of gas and iron that was enclosed in the receiver; and that, without producing any sensible heat!

Emily. How wonderfully quick combustion goes on in pure oxygen gas! But pray, are these drops of burnt iron as heavy as the wire was before?

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* The combustion of steel, as a watch spring, is much more vivid than that of iron. This affords a very beautiful experiment, and is easily made after the oxygen is collected. A bottle of white glass of a quart capacity does well as a receiver. An inch of water at the bottom will prevent its breaking. C.

Mrs. B. They are even heavier; for the iron, in burning, has acquired exactly the weight of the oxygen which has disappeared, and is now combined with it. It has become an oxyd of iron.

Caroline. I do not know what you mean by saying that the oxygen has *disappeared*, Mrs. B., for it was always invisible.

Mrs. B. True, my dear; the expression was incorrect. But though you could not see the oxygen gas, I believe you had no doubt of its presence, as the effect it produced on the wire was sufficiently evident.

Caroline. Yes, indeed; yet you know it was the caloric, and not the oxygen gas itself, that dazzled us so much.

Mrs. B. You are not quite correct in your turn, in saying the caloric dazzled you; for caloric is invisible; it affects only the sense of feeling; it was the light which dazzled you.

Caroline. True; but light and caloric are such constant companions, that it is difficult to separate them, even in idea.

Mrs. B. The easier it is to confound them, the more careful you should be in making the distinction.

Caroline. But why has the water now risen, and filled part of the receiver?

Mrs. B. Indeed, Caroline, I did not suppose you would have asked such a question! I dare say, Emily, you can answer it.

Emily. Let me reflect ...... The oxygen has combined with the wire; the caloric has escaped; consequently nothing can remain in the receiver, and the water will rise to fill the vacuum.

Caroline. I wonder that I did not think of that. I wish that we had weighed the wire and the oxygen gas before combustion; we might then have found whether the weight of the oxyd was equal to that of both.

Mrs. B. You might try the experiment if you particularly wished it; but I can assure you, that, if accurately performed, it never fails to show that the additional weight of the oxyd is precisely equal to that of the oxygen absorbed, whether the process has been a real combustion, or a simple oxygenation.

Caroline. But this cannot be the case with combustions in general; for when any substance is burnt in the common air, so far from increasing in weight, it is evidently diminished, and sometimes entirely consumed.

Mrs. B. But what do you mean by the expression *consumed?* You cannot suppose that the smallest particle of any substance in nature can be actually destroyed. A compound body is decomposed by combustion; some of its constituent parts fly off in a gaseous form, while others remain in a concrete state; the former are called the *volatile*, the latter the *fixed products* of combustion. But if we collect the whole of them, we shall always find that they exceed the weight of the combustible body, by that of the oxygen which has combined with them during combustion.

Emily. In the combustion of a coal fire, then, I suppose that the ashes are what would be called the fixed product, and the smoke the volatile product?

Mrs. B. Yet when the fire burns best, and the quantity of volatile products should be the greatest, there is no smoke; how can you account for that?

Emily Indeed I cannot; therefore I suppose that I was not right in my conjecture.

Mrs. B. Not quite; ashes, as you supposed, are a fixed product of combustion; but smoke, properly speaking, is not one of the volatile products, as it consists of some minute undecomposed particles of the coals which are carried off by the heated air without being burnt, and are either deposited in the form of soot, or dispersed by the wind. Smoke, therefore, ultimately, becomes one of the *fixed* products of combustion. And you may easily conceive that the stronger the fire is, the less smoke is produced, because the fewer particles escape combustion. On this principle depends the invention of Argand's Patent Lamps; a current of air is made to pass through the cylindrical wick of the lamp, by which means it is so plentifully supplied with oxygen, that scarcely a particle of oil escapes combustion, nor is there any smoke produced.

Emily. But what then are the volatile products of combustion?

Mrs. B. Various new compounds, with which you are not yet acquainted, and which being converted by caloric either into vapour or gas, are invisible; but they can be collected, and we shall examine them at some future period.

Caroline. There are then other gases, besides the oxygen and nitrogen gases.

Mrs. B. Yes, several: any substance that can assume and maintain the form of an elastic fluid at the temperature of the atmosphere, is called a gas. We shall examine the several gases in their respective places: but we must now confine our attention to those which compose the atmosphere.

I shall show you another method of decomposing the atmosphere, which is very simple. In breathing, we retain a portion of the oxygen, and expire the nitrogen gas; so that if we breathe in a closed vessel, for a certain length of time, the air within it will be deprived of its oxygen gas. Which of you will make the experiment?

Caroline. I should be very glad to try it.

Mrs. B. Very well; breathe several times through this glass tube into the receiver with which it is connected, until you feel that your breath is exhausted.

Caroline. I am quite out of breath already!

Mrs. B. Now let us try the gas with a lighted taper.

Emily. It is very pure nitrogen gas, for the taper is immediately extinguished.

Mrs. B. That is not a proof of its being pure, but only of the absence of oxygen, as it is that principle alone which can produce combustion, every other gas being absolutely incapable of it.*

Emily. In the methods which you have shown us, for decomposing the atmosphere, the oxygen always abandons the nitrogen; but is there no way of taking the nitrogen from the oxygen, so as to obtain the latter pure from the atmosphere?

Mrs. B. You must observe, that whenever oxygen is taken from the atmosphere, it is by decomposing the oxygen gas; we cannot do the same with the nitrogen gas, because nitrogen has a stronger affinity for caloric than for any other known principle: it appears impossible therefore to separate it from the atmosphere by the power of affinities. But if we cannot obtain the oxygen gas, by this means, in its separate state, we have no difficulty (as you have seen) to procure it in its gaseous form, by taking it from those substances that have absorbed it from the atmosphere, as we did with the oxyd of manganese.

Emily. Can atmospherical air be recomposed, by mixing due proportions of oxygen and nitrogen gases?

Mrs. B. Yes: if about one part of oxygen gas be mixed with about four parts of nitrogen gas, atmospherical air is produced.†

Emily. The air, then, must be an oxyd of nitrogen?

Mrs. B. No, my dear; for it requires a chemical combination between oxygen and nitrogen in order to produce an oxyd; whilst in the atmosphere these two substances are separately combined with caloric, forming two distinct gases, which are simply mixed in the formation of the atmosphere.

I shall say nothing more of oxygen and nitrogen at present, as we shall continually have occasion to refer to them in our future conversations. They are both very abundant in nature; nitrogen is the most plentiful in the atmosphere, and exists also in all animal substances; oxygen forms a constituent part, both of the animal and vegetable kingdoms, from which it may be obtained by a variety of chemical means. But it is now time to conclude our lesson. I am afraid you have learnt more to-day than you will be able to remember.

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* This does not agree with the opinion that *chlorine*, and *iodine* are simple bodies, since they are both supporters of combustion. C.

† The proportion of oxygen in the atmosphere varies from 21 to 22 per cent.

Caroline. I assure you that I have been too much interested in it, ever to forget it. In regard to nitrogen there seems to be but little to remember; it makes a very insignificant figure in comparison to oxygen, although it composes a much larger portion of the atmosphere.

Mrs. B. Perhaps this insignificance you complain of may arise from the compound nature of nitrogen, for though I have hitherto considered it as a simple body, because it is not known in any natural process to be decomposed, yet from some experiments of Sir H. Davy, there appears to be reason for suspecting that nitrogen is a compound body as we shall see afterwards. But even in its simple state, it will not appear so insignificant when you are better acquainted with it; for though it seems to perform but a passive part in the atmosphere, and has no very striking properties, when considered in its separate state, yet you will see by-and bye what a very important agent it becomes, when combined with other bodies. But no more of this at present; we must reserve it for its proper place.

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CONVERSATION VII.

ON HYDROGEN.

Caroline. THE next simple bodies we come to are CHLORINE, and IODINE. Pray what kinds of substances are these; are they also invisible?

Mrs. B. No; for chlorine, in the state of gas, has a distinct greenish colour, and is therefore visible; and iodine, in the same state, has a beautiful claret-red colour. The knowledge of these two bodies, however, and the explanation of their properties, imply various considerations, which you would not yet be able to understand; we shall therefore defer their examination to some future conversation, and we shall pass on to the next simple substance, HYDROGEN, which we cannot, any more than oxygen, obtain in a visible or palpable form. We are acquainted with it only in its gaseous state, as we are with oxygen and nitrogen.

Caroline. But in its gaseous state it cannot be called a simple substance, since it is combined with heat and electricity?

Mrs. B. True, my dear; but as we do not know in nature of any substance which is not more or less combined with caloric and electricity, we are apt to say that a substance is in its pure state when combined with those agents only.

Hydrogen was formerly called *inflammable air*, as it is extremely combustible, and burns with a great flame. Since the invention of the new nomenclature, it has obtained the name of hydrogen, which is derived from two Greek words, the meaning of which is *to produce water*.

Emily. And how does hydrogen produce water?

Mrs. B. By its combustion. Water is composed of eighty-five parts, by weight, of oxygen, combined with fifteen parts of hydrogen; or of two parts, by bulk of hydrogen gas, to one part of oxygen gas.

Caroline. Really! is it possible that water should be a combination of two gases, and that one of these should be inflammable air! Hydrogen must be a most extraordinary gas that will produce both fire and water.

Emily. But I thought you said that combustion could take place in no gas but oxygen?

Mrs. B. Do you recollect what the process of combustion consists in?

Emily. In the combination of a body with oxygen, with disengagement of light and heat.

Mrs. B. Therefore when I say that hydrogen is combustible, I mean that it has an affinity for oxygen; but, like all other combustible substances, it cannot burn unless supplied with oxygen, and also heated to a proper temperature.

Caroline. The simply mixing fifteen parts of hydrogen, with eighty-five parts of oxygen gas, will not, therefore, produce water?

Mrs. B. No; water being a much denser fluid than gases, in order to reduce these gases to a liquid, it is necessary to diminish the quantity of caloric or electricity which maintains them in an elastic form.

Emily. That I should think might be done by combining the oxygen and hydrogen together; for in combining they would give out their respective electricities in the form of caloric, and by this means would be condensed.

Caroline. But you forget, Emily, that in order to make the oxygen and hydrogen combine, you must begin by elevating their temperature, which increases, instead of diminishing, their electric energies.

Mrs. B. Emily is, however, right; for though it is necessary to raise their temperature, in order to make them combine, as that combination affords them the means of parting with their electricities, it is eventually the cause of the diminution of electric energy.

Caroline. You love to deal in paradoxes to-day, Mrs. B.—Fire, then, produces water?

Mrs. B. The combustion of hydrogen gas certainly does; but you do not seem to have remembered the theory of combustion so well as you thought you would. Can you tell me what happens in the combustion of hydrogen gas?

Caroline. The hydrogen combines with the oxygen, and their opposite electricities are disengaged in the form of caloric. —Yes, I think I understand it now—by the loss of this caloric, the gases are condensed into a liquid.

Emily. Water, then, I suppose, when it evaporates and incorporates with the atmosphere, is decomposed and converted into hydrogen and oxygen gases?

Mrs. B. No, my dear—there you are quite mistaken; the decomposition of water is totally different from its evaporation; for in the latter case (as you should recollect) water is only in a state of very minute division; and is merely suspended in the atmosphere, without any chemical combination, and without any separation of its constituent parts. As long as these remain combined, they form WATER, whether in a state of liquidity, or in that of an elastic fluid, as vapour, or under the solid form of ice.

In our experiments on latent heat, you may recollect that we caused water successively to pass through these three forms, merely by an increase or diminution of caloric, without employing any power of attraction, or effecting any decomposition.

Caroline. But are there no means of decomposing water?

Mrs. B. Yes, several; charcoal, and metals, when heated red hot, will attract the oxygen from water, in the same manner as they will from the atmosphere.

Caroline. Hydrogen, I see, is like nitrogen, a poor dependent friend of oxygen, which is continually forsaken for greater favourites.

Mrs. B. The connection, or friendship, as you choose to call it, is much more intimate between oxygen and hydrogen, in the state of water, than between oxygen and nitrogen, in the atmosphere; for, in the first case, there is a chemical union and condensation of the two substances; in the latter, they are simply

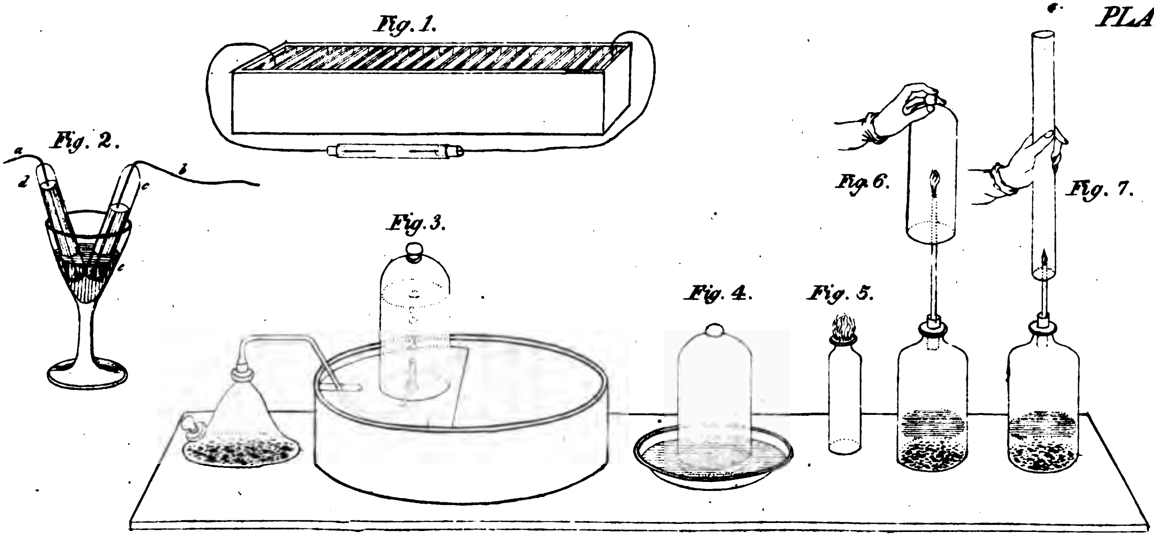

Fig. 1. Apparatus for the decomposition of water by the Voltaic Battery.
Fig. 3. Apparatus for preparing & collecting hydrogen gas._Fig. 4. Receiver full of hydrogen gas inverted over water._Fig. 5. Slow combustion of hydrogen gas._Fig. 6 Apparatus for illustrating the formation of water by the combustion of hydrogen gas._Fig. 7. Apparatus for producing harmonic sounds by the combustion of hydrogen gas._Fig. 2 Apparatus for decomposing water by Voltaic Electricity & obtaining the gasses separate.

mixed together in their gaseous state. You will find, however, that, in some cases, nitrogen is quite as intimately connected with oxygen, as hydrogen is.—But this is foreign to our present subject.

Emily. Water, then, is an oxyd, though the atmospherical air is not?

Mrs. B. It is not commonly called an oxyd, though, according to our definition, it may, no doubt, be referred to that class of bodies.

Caroline. I should like extremely to see water decomposed.

Mrs. B. I can gratify your curiosity by a much more easy process than the oxydation of charcoal or metals: the decomposition of water by these latter means take up a great deal of time, and is attended with much trouble; for it is necessary that the charcoal or metal should be made red hot in a furnace, that the water should pass over them in a state of vapour, that the gas formed should be collected over the water bath, &c. In short, it is a very complicated affair. But the same effect may be produced with the greatest facility, by the action of the Voltaic battery, which this will give me an opportunity of exhibiting.

Caroline. I am very glad of that, for I longed to see the power of this apparatus in decomposing bodies.

Mrs. B. For this purpose I fill this piece of glass-tube (PLATE VIII. Fig. 1.) with water, and cork it up at both ends; through one of the corks I introduce that wire of the battery which conveys the positive electricity; and the wire which conveys the negative electricity is made to pass through the other cork, so that the two wires approach each other sufficiently near to give out their respective electricities.

Caroline. It does not appear to me that you approach the wires so near as you did when you made the battery act by itself.

Mrs. B. Water being a better conductor of electricity than air, the two wires will act on each other at a greater distance in the former than in the latter.

Emily. Now the electrical effect appears: I see small bubbles of air emitted from each wire.

Mrs. B. Each wire decomposes the water, the positive by combining with its oxygen which is negative, the negative by combining with its hydrogen which is positive.

Caroline. That is wonderfully curious! But what are the small bubbles of air?

Mrs. B. Those that appear to proceed from the positive wire, are the result of the decomposition of the water by that wire. That is to say, the positive electricity having combined with some of the oxygen of the water, the particles of hydrogen which were combined with that portion of oxygen are set at liberty, and appear in the form of small bubbles of gas or air.

Emily. And I suppose the negative fluid having in the same manner combined with some of the hydrogen of the water, the particles of oxygen that were combined with it, are set free, and emitted in a gaseous form.

Mrs. B. Precisely so. But I should not forget to observe, that the wires used in this experiment are made of platina, a metal which is not capable of combining with oxygen; for otherwise the wire would combine with the oxygen, and the hydrogen alone would be disengaged.

Caroline. But could not water be decomposed without the electric circle being completed? If, for instance, you immersed only the positive wire in the water, would it not combine with the oxygen, and the hydrogen gas be given out?

Mrs. B. No; for as you may recollect, the battery cannot act unless the circle be completed; since the positive wire will not give out its electricity, unless attracted by that of the negative wire.

Caroline. I understand it now.—But look, Mrs. B., the decomposition of the water which has now been going on for some time, does not sensibly diminish its quantity—what is the reason of that?

Mrs. B. Because the quantity decomposed is so extremely small. If you compare the density of water with that of the gases into which it is resolved, you must be aware that a single drop of water is sufficient to produce thousands of such small bubbles as those you now perceive.

Caroline. But in this experiment, we obtain the oxygen and hydrogen gases mixed together. Is there any means of procuring the two gases separately?

Mrs. B. They can be collected separately with great ease, by modifying a little the experiment. Thus if instead of one tube, we employ two, as you see here (c, d, Plate VIII. fig. 2,) both tubes being closed at one end, and open at the other; and if after filling these tubes with water, we place them standing in a glass of water (e), with their open end downwards, you will see that the moment we connect the wires (a, b) which proceed upwards from the interior of each tube, the one with one end of the battery, and the other with the other end, the water in the tubes will be decomposed; hydrogen will be given out round the wire in the tube connected with the positive end of the battery, and oxygen in the other; and these gases will be evolved exactly in the proportions which I have before mentioned, namely, two measures of hydrogen for one of oxygen. We shall now begin the experiment, but it will be some time before any sensible quantity of the gases can be collected.

Emily. The decomposition of water in this way, slow as it is, is certainly very wonderful; but I confess that I should be still more gratified, if you could show it us on a larger scale, and by a quicker process. I am sorry that the decomposition of water by charcoal or metals is attended with so much inconvenience.

Mrs. B. Water may be decomposed by means of metals without any difficulty: but for this purpose the intervention of an acid is required. Thus, if we add some sulphuric acid (a substance with the nature of which you are not yet acquainted) to the water which the metal is to decompose, the acid disposes the metal to combine with the oxygen of the water so readily and abundantly, that no heat is required to hasten the process. Of this I am going to show you an instance. I put into this bottle the water that is to be decomposed, as also the metal that is to effect that decomposition by combining with the oxygen, and the acid which is to facilitate the combination of the metal and the oxygen. You will see with what violence these will act on each other.*

Caroline. But what metal is it that you employ for this purpose?

Mrs. B. It is iron; and it is used in the state of filings, as these present a greater surface to the acid than a solid piece of metal. For as it is the surface of the metal which is acted upon by the acid, and is disposed to receive the oxygen produced by the decomposition of the water, it necessarily follows that the greater is the surface, the more considerable is the effect. The bubbles which are now rising are hydrogen gas ——

Caroline. How disagreeably it smells! [Pure hydrogen is inodorous. C.]

Mrs. B. It is indeed unpleasant, though, I believe, not particularly hurtful. We shall not, however, suffer any more to escape, as it will be wanted for experiments. I shall, therefore, collect it in a glass-receiver, by making it pass through this bent tube, which will conduct it into the water-bath. (PLATE VIII. fig. 3.)

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* To obtain hydrogen, fit a cork air tight to an oil flask, and pierce it with a burning iron, to admit a tube. The tube may be of glass, lead, or tin, bent to a convenient shape, and put into the opening made by the hot iron. Pour into the flask about a gill of water, and drop into it about an ounce of zinc, granulated by melting, and pouring it into cold water. Then pour in half an ounce by measure of sulphuric acid, and immediately put the cork into its place, and plunge the other end of the tube under a receiver, or large tumbler, filled with water, and inverted in the water-bath. The flask grows hot and the gas begins to rise, the instant the acid is poured in; a place therefore must previously be prepared to set it; and if nothing better is at hand, a bowl, with a cloth in it, to prevent breaking the flask, and set at a convenient height will do very well. C.

Emily. How very rapidly the gas escapes! it is perfectly transparent, and without any colour whatever.—Now the receiver is full ——

Mrs. B. We shall, therefore, remove it, and substitute another in its place. But you must observe, that when the receiver is full, it is necessary to keep it inverted with the mouth under water, otherwise the gas would escape. And in order that it may not be in the way, I introduce within the bath, under the water, a saucer, into which I slide the receiver, so that it can be taken out of the bath and conveyed any where, the water in the saucer being equally effectual in preventing its escape as that in the bath. (PLATE VIII. fig. 4.)

Emily. I am quite surprised to see what a large quantity of hydrogen gas can be produced by such a small quantity af water, especially as oxygen is the principal constituent of water.

Mrs. B. In weight it is; but not in volume. For though the proportion, by weight, is nearly six parts of oxygen to one of hydrogen, yet the proportion of the volume of the gases, is about one part of oxygen to two of hydrogen; so much heavier is the former than the latter.*

Caroline. But why is the vessel in which the water is decomposed so hot? As the water changes from a liquid to a gaseous form, cold should be produced instead of heat.

Mrs. B. No; for if one of the constituents of water is converted into a gas, the other becomes solid in combining with the metal.

Emily. In this case, then, neither heat nor cold should be produced?

Mrs. B. True; but observe that the sensible heat which is disengaged in this operation, is not owing to the decomposition of the water, but to an extrication of heat produced by the mixture of water and sulphuric acid. I will mix some water and sulphuric acid together in this glass, that you may feel the surprising quantity of heat which is disengaged by their union—now take hold of the glass ——

Caroline. Indeed I cannot; it feels as hot as boiling water. I should have imagined there would have been heat enough disengaged to have rendered the liquid solid.

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* Hydrogen is about thirteen times lighter than atmospheric air. C.

Mrs. B. As, however, it does not produce that effect, we cannot refer this heat to the modification called latent heat. We may, however, I think, consider it as heat of capacity, since the liquid is condensed by its loss; and if you were to repeat the experiment, in a graduated tube, you would find that the two liquids, when mixed, occupy considerably less space than they did separately.—But we will reserve this to another opportunity, and attend at present to the hydrogen gas which we have been producing.

If I now set the hydrogen gas, which is contained in this receiver, at liberty all at once, and kindle it as soon as it comes in contact with the atmosphere, by presenting it to a candle, it will so suddenly and rapidly decompose the oxygen gas, by combining with its basis, that an explosion, or a *detonation* (as chemists commonly call it,) will be produced. For this purpose, I need only take up the receiver, and quickly present its open mouth to the candle——so . . . . . .

Caroline. It produced only a sort of hissing noise, with a vivid flash of light. I had expected a much greater report.

Mrs. B. And so it would have been, had the gases been closely confined at the moment they were made to explode. If, for instance, we were to put in this bottle a mixture of hydrogen gas and atmospheric air; and if, after corking the bottle, we should kindle the mixture by a very small orifice, from the sudden dilatation of the gases at the moment of their combination, the bottle must either fly to pieces, or the cork be blown out with considerable violence.

Caroline. But in the experiment which we have just seen, if you did not kindle the hydrogen gas, would it not equally combine with the oxygen?

Mrs. B. Certainly not; for, as I have just explained to you, it is necessary that the oxygen and hydrogen gases be burnt together, in order to combine chemically and produce water.

Caroline. That is true; but I thought this was a different combination, for I see no water produced.

Mrs. B. The water resulting from this detonation was so small in quantity, and in such a state of minute division, as to be invisible. But water certainly was produced; for oxygen is incapable of combining with hydrogen in any other proportions than those which form water; therefore water must always be the result of their combination.

If, instead of bringing the hydrogen gas into sudden contact with the atmosphere (as we did just now) so as to make the whole of it explode the moment it is kindled, we allow but a very small surface of gas to burn in contact with the atmosphere, the combustion goes on quietly and gradually at the point of contact, without any detonation, because the surfaces brought together are too small for the immediate union of gases. The experiment is a very easy one. This phial, with a narrow neck, (PLATE VIII. fig 5.) is full of hydrogen gas, and is carefully corked. If I take out the cork without moving the phial, and quickly approach the candle to the orifice, you will see how different the result will be*——

Emily. How prettily it burns, with a blue flame! The flame is gradually sinking within the phial—now it has entirely disappeared. But does not this combustion likewise produce water?

Mrs. B. Undoubtedly. In order to make the formation of the water sensible to you, I shall procure a fresh supply of hydrogen gas, by putting into this bottle (PLATE VIII. fig. 6.) iron-filings, water, and sulphuric acid, materials similar to those which we have just used for the same purpose. I shall then cork up the bottle, leaving only a small orifice in the cork, with a piece of glass-tube fixed to it, through which the gas will issue in a continued rapid stream.

Caroline. I hear already the hissing of the gas through the tube, and I can feel a strong current against my hand.

Mrs. B. This current I am going to kindle with the candle —see how vividly it burns——

Emily. It burns like a candle with a long flame. But why does this combustion last so much longer than in the former experiment?

Mrs. B. The combustion goes on interruptedly as long as the new gas continues to be produced. Now if I invert this receiver over the flame, you will soon perceive its internal surface covered with a very fine dew, which is pure water——†

Caroline. Yes, indeed; the glass is now quite dim with moisture! How glad I am that we can *see* the water produced by this combustion.

Emily. It is exactly what I was anxious to see; for I confess I was a little incredulous.

Mrs. B. If I had not held the glass-bell over the flame, the water would have escaped in the state of vapour, as it did in the former experiment. We have, here, of course, obtained but a very small quantity of water; but the difficulty of producing a proper apparatus, with sufficient quantities of gases, prevents my showing it you on a larger scale.

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* The levity of hydrogen is such, that if a vessel be filled with it, and kept inverted, it may be carried about the room, without its escaping. The above experiment therefore may be made by bringing a small jar, or tumbler of the gas over a lighted lamp. C.

† The burning of a candle, lamp, wood &c. always produces water. The tallow and oil contain hydrogen, and during combustion, it unites with the oxygen of the atmosphere. Hold a wide tube over a lamp, and it is soon covered with moisture. Wood contains hydrogen. C.

The composition of water was discovered about the same period, both by Mr. Cavendish, in this country, and by the celebrated French chemist, Lavoisier. The latter invented a very perfect and ingenious apparatus to perform, with great accuracy, and upon a large scale, the formation of water by the combination of oxygen and hydrogen gases. Two tubes, conveying due proportions, the one of oxygen, the other of hydrogen gas, are inserted at opposite sides of a large globe of glass, previously exhausted of air; the two streams of gas are kindled within the globe, by the electrical spark, at the point where they come in contact; they burn together, that is to say, the hydrogen combines with the oxygen, the caloric is set at liberty, and a quantity of water is produced exactly equal, in weight, to that of the two gases introduced into the globe.

Caroline. And what was the greatest quantity of water ever formed in this apparatus?

Mrs. B. Several ounces; indeed, very nearly a pound, if I recollect right; but the operation lasted many days.

Emily. This experiment must have convinced all the world of the truth of the discovery. Pray, if improper proportions of the gases were mixed and set fire to, what would be the result?

Mrs. B. Water would equally be formed, but there would be a residue of either one or other of the gases, because, as I have already told you, hydrogen and oxygen will combine only in the proportions requisite for the formation of water.

Emily. Look, Mrs. B., our experiment with the Voltaic battery (PLATE VIII. fig. 2.) has made great progress; a quantity of gas has been formed in each tube, but in one of them there is twice as much as in the other.

Mrs. B. Yes; because, as I said before, water is composed of two volumes of hydrogen to one of oxygen—and if we should now mix these gases together and set fire to them by an electrical spark, both gases would entirely disappear, and a small quantity of water would be formed.

There is another curious effect produced by the combustion of hydrogen gas, which I shall show you, though I must acquaint you first, that I cannot well explain the cause of it. For this purpose, I must put some materials into our apparatus, in order to obtain a stream of hydrogen gas, just as we have done before. The process is already going on, and the gas is rushing through the tube—I shall now kindle it with the taper——

Emily. It burns exactly as it did before——What is the curious effect which you were mentioning?

Mrs. B. Instead of the receiver, by means of which we have just seen the drops of water form, we shall invert over the flame this piece of tube, which is about two feet in length, and one inch in diameter (PLATE VIII. fig. 7.;) but you must observe that it is open at both ends.

Emily. What a strange noise it makes! something like the Æolian harp, but not so sweet.

Caroline. It is very singular, indeed; but I think rather too powerful to be pleasing. And is not this sound accounted for?

Mrs. B. That the percussion of glass, by a rapid stream of gas, should produce a sound, is not extraordinary: but the sound here is so peculiar, that no other gas has a similar effect. Perhaps it is owing to a brisk vibratory motion of the glass, occasioned by the successive formation and condensation of small drops of water on the sides of the glass tube, and the air rushing in to replace the vacuum formed.*

Caroline. How very much this flame resembles the burning of a candle.

Mrs. B. The burning of a candle is produced by much the same means. A great deal of hydrogen is contained in candles, whether of tallow or wax. This hydrogen being converted into gas by the heat of the candle, combines with the oxygen of the atmosphere, and flame and water result from this combination.† So that, in fact, the flame of a candle is owing to the combustion of hydrogen gas. An elevation of temperature, such as is produced by a lighted match or taper, is required to give the first impulse to the combustion; but afterwards it goes on of itself, because the candle finds a supply of caloric in the successive quantities of heat which results from the union of the two electricities given out by the gases during their combustion. But there are other circumstances connected with the combustion of candles and lamps, which I cannot explain to you till you are acquainted with *carbon*, which is one of their constituent parts. In general, however, whenever you see flame, you may infer that it is owing to the formation and burning of hydrogen gas;‡ for flame is the peculiar mode of burning hydrogen gas, which, with only one or two apparent exceptions, does not belong to any other combustible.

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* This ingenious explanation was first suggested by Dr. Delarive.—See Journals of the Royal Institution, vol. i. p. 259.

† The candle also contains carbon, which gives brilliancy to the flame, and the product of the combination besides flame and water is a quantity of carbonic acid.

‡ Or rather *hydro-carbonat*, a gas composed of hydrogen and carbon, which will be noticed under the head *Carbon*.

Emily. You astonish me! I understood that flame was the caloric produced by the union of the two electricities, in all combustions whatever?

Mrs. B. Your error proceeded from your vague and incorrect idea of flame; you have confounded it with light and caloric in general. Flame always implies caloric, since it is produced by the combustion of hydrogen gas; but all caloric does not imply flame. Many bodies burn with intense heat without producing flame. Coals, for instance, burn with flame until all the hydrogen which they contain is evaporated; but when they afterwards become red hot, much more caloric is disengaged than when they produce flame.

Caroline. But the iron wire, which you burnt in oxygen gas, appeared to me to emit flame; yet, as it was a simple metal, it could contain no hydrogen?

Mrs. B. It produced a sparkling dazzling blaze of light, but no real flame.

Caroline. And what is the cause of the regular shape of the flame of a candle?

Mrs. B. The regular stream of hydrogen gas which exhales from its combustible matter.

Caroline. But the hydrogen gas must, from its great levity, ascend into the upper regions of the atmosphere: why therefore does not the flame continue to accompany it?

Mrs. B. The combustion of the hydrogen gas is completed at the point where the flame terminates; it then ceases to be hydrogen gas, as it is converted by its combination with oxygen into watery vapour; but in a state of such minute division as to be invisible.

Caroline. I do not understand what is the use of the wick of a candle, since the hydrogen gas burns so well without it?

Mrs. B. The combustible matter of the candle must be decomposed in order to emit the hydrogen gas, and the wick is instrumental in effecting this decomposition. Its combustion first melts the combustible matter, and......

Caroline. But in lamps the combustible matter is already fluid, and yet they also require wicks?

Mrs. B. I am going to add that, afterwards, the burning wick (by the power of capillary attraction) gradually draws up the fluid to the point where combustion takes place; for you must have observed that the wick does not burn quite to the bottom.

Caroline. Yes; but I do not understand why it does not.

Mrs. B. Because the air has not so free an access to that part of the wick which is immediately in contact with the candle, as to the part just above, so that the heat there is not sufficient to produce its decomposition; the combustion therefore begins a little above this point.*

Caroline. But, Mrs. B. in those beautiful lights, called *gas-lights*, which are now seen in many streets, and will, I hope, be soon adopted every where, I can perceive no wick at all. How are these lights managed?

Mrs. B. I am glad you have put me in mind of saying a few words on this very useful and interesting improvement. In this mode of lighting, the gas is conveyed to the extremity of a tube, where it is kindled, and burns as long as the supply continues. There is, therefore, no occasion for a wick, or any other fuel whatever.

Emily. But how is this gas procured in such large quantities?

Mrs. B. It is obtained from coal, by distillation.—Coal, when exposed to heat in a close vessel, is decomposed; and hydrogen, which is one of its constituents, rises in the state of gas, combined with another of its component parts, carbon, forming a compound gas, called *Hydro-carbonat*, the nature of which we shall again have an opportunity of noticing when we treat of carbon. This gas, like hydrogen, is perfectly transparent, invisible, and highly inflammable; and in burning it emits that vivid light which you have so often observed.

Caroline. And does the process for procuring it require nothing but heating the coals, and conveying the gas through tubes?

Mrs. B. Nothing else; except that the gas must be made to pass, immediately at its formation, through two or three large vessels of water,† in which it deposits some other ingredients, and especially water, tar, and oil, which also arise from the distillation of coals. The gas-light apparatus, therefore consists simply in a large iron vessel, in which the coals are exposed to the heat of a furnace,—some reservoirs of water, in

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* In the burning of a candle, the reason why combustion does not take place in immediate contact with the tallow is, that the caloric is here employed in converting a solid into a fluid, as explained in the conversation of free caloric. In the burning of a lamp if the same thing takes place, it is because the metallic tube through which the wick passes, conducts off the heat. C.

† The gas is passed through one vessel of slacked lime and water to absorb the *carbonic acid gas*, with which it is always more or less mixed, when first distilled. C.

PLATE IX.

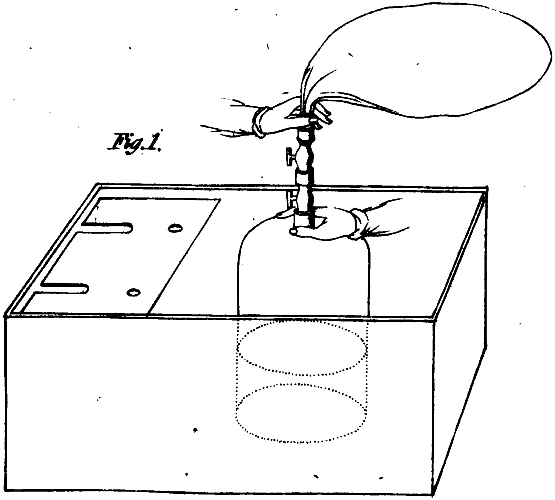

Fig.1.

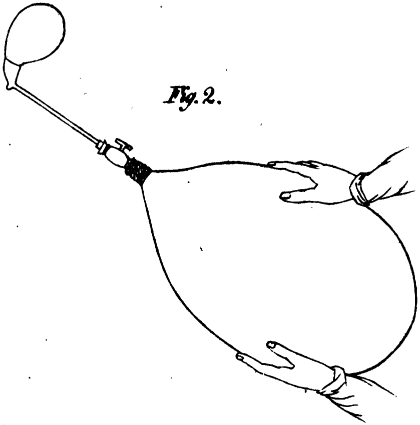

Fig.2.

Fig.1. Apparatus for transferring gases from a Receiver into a bladder.—Fig.2. Apparatus for blowing Soap bubbles.

which the gas deposits its impurities,—and tubes that convey it to the desired spot, being propelled with uniform velocity through the tubes by means of a certain degree of pressure which is made upon the reservoir.

Emily. What an admirable contrivance! Do you not think, Mrs. B., that it will soon get into universal use?

Mrs. B. Most probably, for the purpose of lighting streets, offices, and public places, as it far surpasses any former invention for that purpose; but in regard to the interior of private houses, this mode of lighting has not yet been sufficiently tried to know whether it will be found generally desirable, either with respect to economy or convenience. It may, however, be considered as one of the happiest applications of chemistry to the comforts of life; and there is every reason to suppose that it will answer the full extent of public expectation.

I have another experiment to show you with hydrogen gas, which I think will entertain you. Have you ever blown bubbles with soap and water?

Emily. Yes, often, when I was a child; and I used to make them float in the air by blowing them upwards.

Mrs. B. We shall fill some such bubbles with hydrogen gas, instead of atmospheric air, and you will see with what ease and rapidity they will ascend, without the assistance of blowing, from the lightness of the gas.—Will you mix some soap and water whilst I fill this bladder with the gas contained in the receiver which stands on the shelf in the water-bath?

Caroline. What is the use of the brass-stopper and turn-cock at the top of the receiver?

Mrs. B. It is to afford a passage to the gas when required. There is, you see, a similar stop-cock fastened to this bladder, which is made to fit that on the receiver. I screw them one on the other, and now turn the two cocks, to open a communication between the receiver and the bladder; then, by sliding the receiver off the shelf, and gently sinking it into the bath, the water rises in the receiver and forces the gas into the bladder. (PLATE IX. fig. 1.)

Caroline. Yes, I see the bladder swell as the water rises in the receiver.

Mrs. B. I think that we have already a sufficient quantity in the bladder for our purpose; we must be careful to stop both the cocks before we separate the bladder from the receiver, lest the gas should escape.—Now I must fix a pipe to the stopper of the bladder, and by dipping its mouth into the soap and water, take up a few drops—then I again turn the cock, and squeeze the bladder in order to force the gas into the soap and water at the mouth of the pipe. (PLATE IX. fig. 2.)

Emily. There is a bubble—but it bursts before it leaves the mouth of the pipe.

Mrs. B. We must have patience and try again; it is not so easy to blow bubbles by means of a bladder, as simply with the breath.

Caroline. Perhaps there is not soap enough in the water; I should have had warm water, it would have dissolved the soap better.

Emily. Does not some of the gas escape between the bladder and the pipe?

Mrs. B. No, they are perfectly air tight; we shall succeed presently, I dare say.

Caroline. Now a bubble ascends; it moves with the rapidity of a balloon. How beautifully it refracts the light!

Emily. It has burst against the ceiling—you succeed now wonderfully; but why do they all ascend and burst against the ceiling?

Mrs. B. Hydrogen gas is so much lighter than atmospherical air, that it ascends rapidly with its very light envelope, which is burst by the force with which it strikes the ceiling.

Air-balloons are filled with this gas, and if they carried no other weight than their covering, would ascend as rapidly as these bubbles.

Caroline. Yet their covering must be much heavier than that of these bubbles?

Mrs. B. Not in proportion to the quantity of gas they contain. I do not know whether you have ever been present at the filling of a large balloon. The apparatus for that purpose is very simple. It consists of a number of vessels, either jars or barrels, in which the materials for the formation of the gas are mixed, each of these being furnished with a tube, and communicating with a long flexible pipe, which conveys the gas into the balloon.

Emily. But the fire-balloons which were first invented, and have been since abandoned, on account of their being so dangerous, were constructed, I suppose, on a different principle.

Mrs. B. They were filled simply with atmospherical air, considerably rarified by heat; and the necessity of having a fire underneath the balloon, in order to preserve the rarefaction of the air within it, was the circumstance productive of so much danger.

If you are not yet tired of experiments, I have another to show you. It consists in filling soap-bubbles with a mixture of hydrogen and oxygen gases, in the proportions that form water; and afterwards setting fire to them.

Emily. They will detonate, I suppose?

Mrs. B. Yes, they will. As you have seen the method of transferring the gas from the receiver into the bladder, it is not necessary to repeat it. I have therefore provided a bladder which contains a due proportion of oxygen and hydrogen gases, and we have only to blow bubbles with it.

Caroline. Here is a fine large bubble rising—shall I set fire to it with the candle?

Mrs. B. If you please......

Caroline. Heavens, what an explosion!*—It was like the report of a gun: I confess it frightened me much. I never should have imagined it could be so loud.

Emily. And the flash was as vivid as lightning.

Mrs. B. The combination of the two gases takes place during that instant of time that you see the flash, and hear the detonation.

Emily. This has a strong resemblance to thunder and lightning.†

Mrs. B. These phenomena, however, are generally of an electrical nature. Yet various meteorological effects may be attributed to accidental detonations of hydrogen gas in the atmosphere; for nature abounds with hydrogen: it constitutes a very considerable portion of the whole mass of water belonging to our globe, and from that source almost every other body obtains it. It enters into the composition of all animal substances, and of a great number of minerals; but it is most abundant in vegetables. From this immense variety of bodies, it is often spontaneously disengaged; its great levity makes it rise into the superior regions of the atmosphere; and when, either by an electrical spark, or any casual elevation of temperature, it takes fire, it may produce such meteors or luminous appearances as are occasionally seen in the atmosphere. Of this kind are probably those broad flashes which we often see on a summer-evening, without hearing any detonation.

Emily. Every flash, I suppose, must produce a quantity of water?

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* In making this experiment, always be careful to turn the stop-cock, or detach the bubble completely from the pipe before it is set fire to; otherwise a sad accident may happen from the gas taking fire in the bladder. C.

† The report is owing to the air, rushing in to fill the vacuum, caused by the condensation of the two gasses and the heat extricated at the same instant. C.

Caroline. And this water, naturally, descends in the form of rain?

Mrs. B. That probably is often the case, though it is not a necessary consequence; for the water may be dissolved by the atmosphere, as it descends towards the lower regions, and remain there in the form of clouds.

The application of electrical attraction to chemical phenomena is likely to lead to many very interesting discoveries in meteorology; for electricity evidently acts a most important part in the atmosphere. This subject however is, as yet, not sufficiently developed for me to venture enlarging upon it. The phenomena of the atmosphere are far from being well understood; and even with the little that is known, I am but imperfectly acquainted.

But before we take leave of hydrogen, I must not omit to mention to you a most interesting discovery of Sir H. Davy, which is connected with this subject.

Caroline. You allude, I suppose, to the new miner's lamp, which has of late been so much talked of? I have long been desirous of knowing what that discovery was, and what purpose it was intended to answer.

Mrs. B. It often happens in coal-mines, that quantities of the gas, called by chemists *hydro-carbonat*, or by the miners *fire-damp*, (the same from which the gas-lights are obtained,) ooze out from fissures in the beds of coal, and fill the cavities in which the men are at work; and this gas being inflammable, the consequence is, that when the men approach those places with a lighted candle, the gas takes fire, and explosions happen which destroy the men and horses employed in that part of the colliery, sometimes in great numbers.

Emily. What tremendous accidents these must be! But whence does that gas originate?

Mrs. B. Being the chief product of the combustion of coal, no wonder that inflammable gas should occasionally appear in situations in which this mineral abounds, since there can be no doubt that processes of combustion are frequently taking place at a great depth under the surface of the earth; and therefore those accumulations of gas may arise either from combustions actually going on, or from former combustions, the gas having perhaps been confined there for ages.

Caroline. And how does Sir H. Davy's lamp prevent those dreadful explosions?

Mrs. B. By a contrivance equally simple and ingenious; and one which does no less credit to the philosophical views from which it was deduced, than to the philanthropic motives from which the enquiry sprung. The principle of the lamp is shortly this: It was ascertained, two or three years ago, both by Mr. Tenant and by Sir Humphrey himself, that the combustion of inflammable gas could not be propagated through small tubes; so that if a jet of an inflameable gaseous mixture, issuing from a bladder or any other vessel, through a small tube, be set fire to, it burns at the orifice of the tube, but the flame never penetrates into the vessel. It is upon this fact that Sir Humphrey's safety lamp is founded.

Emily. But why does not the flame ever penetrate through the tube into the vessel from which the gas issues, so as to explode at once the whole of the gas?

Mrs. B. Because, no doubt, the inflamed gas is so much cooled in its passage through a small tube as to cease to burn before the combustion reaches the reservoir.

Caroline. And how can this principle be applied to the construction of a lamp!

Mrs. B. Nothing easier. You need only suppose a lamp enclosed all round in glass or horn, but having a number of small open tubes at the bottom, and others at the top, to let the air in and out. Now, if such a lamp or lanthorn be carried into an atmosphere capable of exploding, an explosion or combustion of the gas will take place *within* the lamp; and although the vent afforded by the tubes will save the lamp from bursting, yet, from the principle just explained, the combustion will not be propagated to the external air through the tubes, so that no farther consequence will ensue.

Emily. And is that all the mystery of that valuable lamp?

Mrs. B. No; in the early part of the enquiry a lamp of this kind was actually proposed; but it was but a rude sketch compared to its present state of improvement. Sir H. Davy, after a succession of trials, by which he brought his lamp nearer and nearer to perfection, at last conceived the happy idea that if the lamp were surrounded with a wire-work or wire-gauze, of a close texture, instead of glass or horn, the tubular contrivance I have just described would be entirely superseded, since each of the interstices of the gauze would act as a tube in preventing the propagation of explosions; so that this previous metallic covering would answer the various purposes of transparency, of permeability to air, and of protection against explosion. This idea, Sir Humphrey immediately submitted to the test of experiment, and the result has answered his most sanguine expectations, both in his laboratory and in the collieries, where it has already been extensively tried. And he has now the happiness of thinking that his invention will probably be the means of saving every year a number of lives, which would have been lost in digging out of the bowels of the earth one of the most valuable necessaries of life. Here is one of these lamps, every part of which you will at once comprehend. (See PLATE X. fig. 1.)

Caroline. How very simple and ingenious! But I do not yet well see why an explosion taking place within the lamp should not communicate to the external air around it, through the interstices of the wire?

Mrs. B. This has been and is still a subject of wonder, even to philosophers; and the only mode of explaining it is, that flame or ignition cannot pass through a fine wire-work, because the metallic wire cools the flame sufficiently to extinguish it in passing through the gauze. This property of the wire-gauze is quite similar to that of the tubes which I mentioned on introducing the subject; for you may consider each interstice of the gauze as an extremely short tube of a very small diameter.

Emily. But I should expect the wire would often become red-hot, by the burning of the gas within the lamp?

Mrs. B. And this is actually the case, for the top of the lamp is very apt to become red-hot. But, fortunately, inflammable gaseous mixtures cannot be exploded by red-hot wire, the intervention of actual flame being required for that purpose; so that the wire does not set fire to the explosive gas around it.

Emily. I can understand that; but if the wire be red-hot, how can it cool the flame within, and prevent its passing through the gauze?

Mrs. B. The gauze, though red-hot, is not so hot as the flame by which it has been heated; and as metalic wire is a good conductor, the heat does not much accumulate in it, as it passes off quickly to the other parts of the lamp, as well as to any contiguous bodies.

Caroline. This is indeed a most interesting discovery, and one which shows at once the immense utility with which science may be practically applied to some of the most important purposes.

CONVERSATION VIII.

ON SULPHUR AND PHOSPHORUS.

Mrs. B. SULPHUR is the next substance that comes under our consideration. It differs in one essential point from the pre-

PLATE X.

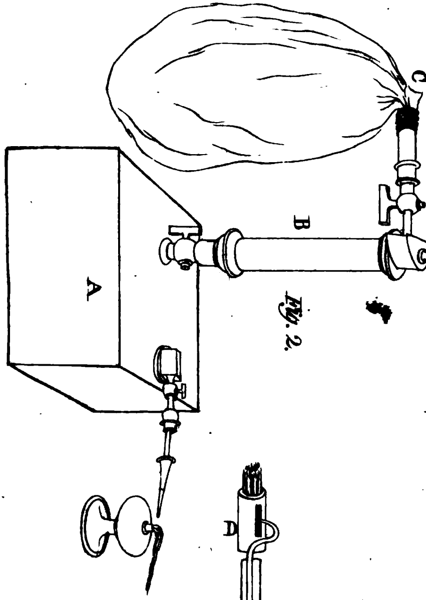
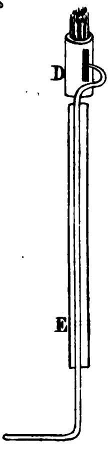


Fig. 2.



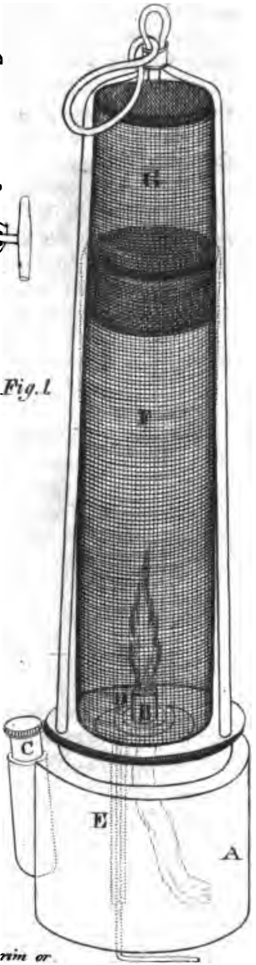


Fig. 1.

Fig. 1. A. the cistern containing the oil.—B. the rim or
screw by which the gauze cage is fixed to the cistern.—C. apperture for
supplying oil.—E. a wire for trimming the wick D.—F. the wire gauze cylinder.
G. a double top.—Fig. 2. A. the reservoir of condensed air.—B. the condensing
syringe.—C. the bladder for oxygen.—D. the moveable jet.

PLATE XI.

Fig. 1.
Sublimation of Sulphur.

Fig. 2.

Fig. 3.
Decomposition of water by Carbon.

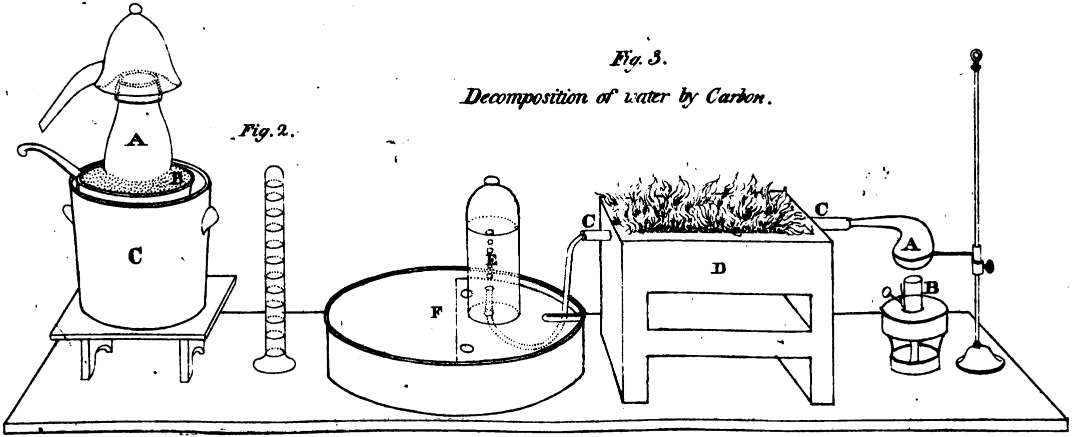


Fig. 1. A *Alembic.*_B *Sand bath.*_C *Furnace.*_*Fig. 2. Eudiometer.*_*Fig. 3.* A *Retort containing water.*_B *Lamp to heat the water* CC *Porcelain tube containing Carbone.*_D *Furnace through which the tube passes.*_E *Receiver for the gas produced.*_F *Water bath.*

ceding, as it exists in a solid form at the temperature of the atmosphere.

Caroline. I am glad that we have at last a solid body to examine; one that we can see and touch. Pray, is it not with sulphur that the points of matches are covered, to make them easily kindle?

Mrs. B. Yes, it is; and you therefore already know that sulphur is a very combustible substance. It is seldom discovered in nature in a pure unmixed state; so great is its affinity for other substances, that it is almost constantly found combined with some of them. It is most commonly united with metals, under various forms, and is separated from them by a very simple process. It exists likewise in many mineral waters, and some vegetables yield it in various proportions, especially those of the cruciform tribe. It is also found in animal matter; in short it may be discovered in greater or less quantity, in the mineral, vegetable, and animal kingdoms.*

Emily. I have heard of *flowers of sulphur*, are they the produce of any plant?

Mrs. B. By no means: they consist of nothing more than common sulphur, reduced to a very fine powder by a process called *sublimation.*—You see some of it in this phial; it is exactly the same substance as this lump of sulphur, only its colour is a paler yellow, owing to its state of very minute division.

Emily. Pray what is sublimation?

Mrs. B. It is the evaporation, or, more properly speaking, the volatilisation of solid substances, which, in cooling, condense again in a concrete form. The process, in this instance, must be performed in a closed vessel, both to prevent combustion, which would take place if the access of air were not carefully precluded, and likewise in order to collect the substance after the operation. As it is rather a slow process, we shall not try the experiment now; but you will understand it perfectly if I show you the apparatus used for the purpose. (PLATE XI. fig. 1.) Some lumps of sulphur are put into a receiver of this kind, which is called a *cucurbit.* Its shape, you see, somewhat resembles that of a pear, and is open at the top, so as to adapt itself exactly to a kind of conical receiver of this sort, called the head. The cucurbit, thus covered with its head, is placed over a sand-bath: this is nothing more than a vessel full of sand, which is kept heated by a furnace, such as you see here, so as to preserve the apparatus in a moderate and uniform temperature. The sulphur then soon begins to melt, and immediately after this, a thick white smoke rises, which is gradually deposited within the head, or upper part of the apparatus, where it condenses against the sides, somewhat in the form of a vegetation, whence it has obtained the name of flowers of sulphur. This apparatus, which is called an *alembic*, is highly useful in all kinds of distillations, as you will see when we come to treat of those operations. Alembics are not commonly made of glass, like this, which is applicable only to distillations upon a very small scale. Those used in manufactures are generally made of copper, and are, of course, considerably larger. The general construction, however, is always the same, although their shape admits of some variation.

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* The sulphur of commerce is chiefly obtained in the vicinity of volcanoes, or in volcanic countries, where it is brought up from the bowels of the earth by *sublimation.* An inferior kind is obtained by the distillation of pyrites. C

Caroline. What is the use of that neck, or tube, which bends down from the upper piece of the apparatus?

Mrs. B. It is of no use in sublimations; but in distillations (the general object of which is to evaporate, by heat, in closed vessels, the volatile parts of a compound body, and to condense them again into a liquid,) it serves to carry off the condensed fluid, which otherwise would fall back into the cucurbit. But this is rather foreign to our present subject. Let us return to the sulphur. You now perfectly understand, I suppose, what is meant by sublimation?

Emily. I believe I do. Sublimation appears to consist in destroying, by means of heat, the attraction of aggregation of the particles of a solid body, which are thus volatilised; and as soon as they lose the caloric which produced that effect, they are deposited in the form of a fine powder.

Caroline. It seems to me to be somewhat similar to the transformation of water into vapour, which returns to its liquid state when deprived of caloric.

Emily. There is this difference, however, that the sulphur does not return to its former state, since instead of lumps, it changes to a fine powder.

Mrs. B. Chemically speaking, it is exactly the same substance, whether in the form of lump or powder. For if this powder be melted again by heat, it will, in cooling, be restored to the same solid state in which it was before its sublimation.

Caroline. But if there be no real change, produced by the sublimation of the sulphur, what is the use of that operation?

Mrs. B. It divides the sulphur into very minute parts, and thus disposes it to enter more readily into combination with other bodies. It is used also as a means of purification.

Caroline. Sublimation appears to me, like the beginning of combustion, for the completion of which one circumstance only is wanting, the absorption of oxygen.

Mrs. B. But that circumstance is every thing. No essential alteration is produced in sulphur by sublimation; whilst in combustion it combines with the oxygen, and forms a new compound totally different in every respect from Sulphur in its pure state.—We shall now *burn* some sulphur, and you will see how very different the result will be. For this purpose I put a small quantity of flowers of sulphur into this cup, and place it in a dish, into which I have poured a little water: I now set fire to the sulphur with the point of this hot wire; for its combustion will not begin unless its temperature be considerably raised.—You see that it burns with a faint blueish flame: and as I invert over it this receiver, white fumes arise from the sulphur, and fill the vessel.—You will soon perceive that the water is rising within the receiver, a little above its level in the plate. Well, Emily, can you account for this?

Emily. I suppose that the sulphur has absorbed the oxygen from the atmospherical air within the receiver, and that we shall find some oxygenated sulphur in the cup. As for the white smoke, I am quite at a loss to guess what it may be.

Mrs. B. Your first conjecture is very right; but you are mistaken in the last; for nothing will be left in the cup. The white vapour is the oxygenated sulphur, which assumes the form of an elastic fluid of a pungent and offensive smell, and is a powerful acid. Here you see a chemical combination of oxygen and sulphur, producing a true gas, which would continue such under the pressure and at the temperature of the atmosphere, if it did not unite with the water in the plate, to which it imparts its acid taste, and all its acid properties. You see, now, with what curious effects the combustion of sulphur is attended.

Caroline. This is something quite new; and I confess that I do not perfectly understand why the sulphur turns acid.

Mrs. B. It is because it unites with oxygen, which is the acidifying principle. And, indeed, the word *oxygen* is derived from two Greek words, signifying *to produce an acid.*

Caroline. Why, then, is not water, which contains such a quantity of oxygen, acid?

Mrs. B. Because hydrogen, which is the other constituent of water, is not susceptible of acidification.—I believe it will be necessary, before we proceed further, to say a few words of the general nature of acids, though it is rather a deviation from our plan of examining the simple bodies separately, before we consider them in a state of combination.

Acids may be considered as a peculiar class of *burnt** bodies, which during their combustion, or combination with oxygen, have acquired very characteristic properties. They are chiefly discernible by their sour taste, and by turning red most of the blue vegetable colours. These two properties are common to the whole class of acids; but each of them is distinguished by other peculiar qualities. Every acid consists of some particular substance, (which constitutes its basis, and is different in each,) and of oxygen, which is common to them all.

Emily. But I do not clearly see the difference between acids and oxyds.

Mrs. B. Acids were, in fact, oxyds, which, by the addition of a sufficient quantity of oxygen, have been converted into acids. For acidification, you must observe, always implies previous oxydation, as a body must have combined with the quantity of oxygen requisite to constitute it an oxyd, before it can combine with the greater quantity which is necessary to render it an acid.

Caroline. Are all oxyds capable of being converted into acids?

Mrs. B. Very far from it; it is only certain substances which will enter into that peculiar kind of union with oxygen that produces acids, and the number of these is proportionally very small; but all burnt bodies may be considered as belonging either to the class of oxyds, or to that of acids. At a future period, we shall enter more at large into this subject. At present, I have but one circumstance further to point out to your observation respecting acids: it is, that most of them are susceptible of two degrees of acidification, according to the different quantities of oxygen with which their basis combines.

Emily. And how are these two degrees of acidification distinguished?

Mrs. B. By the peculiar properties which result from them. The acid we have just made is the first or weakest degree of acidification, and is called *sulphureous acid;* if it were fully saturated with oxygen, it would be called *sulphuric acid.* You must therefore remember, that in this, as in all acids, the first degree of acidification is expressed by the termination in *ous;* the stronger, by the termination in *ic.*

Caroline. And how is the sulphuric acid made?

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* This might mislead the student. The acids are not all of them formed by burning. All the vegetable acids, as the citric, malic, &c. exist ready formed; some of them are contained in fruits, as in lemons, apples, &c. C.

Mrs. B. By burning sulphur in pure oxygen gas, and thus rendering its combustion much more complete. I have provided some oxygen gas for this purpose; it is in that bottle, but we must first decant the gas into the glass receiver which stands on the shelf in the bath, and is full of water.

Caroline. Pray, let me try to do it, Mrs. B.

Mrs. B. It requires some little dexterity—hold the bottle completely under water, and do not turn the mouth upwards, till it is immediately under the aperture in the shelf, through which the gas is to pass into the receiver, and then turn it up gradually.—Very well, you have only let a few bubbles escape, and that must be expected at first trial. Now I shall put this piece of sulphur into the receiver, through the opening at the top, and introduce along with it a small piece of lighted tinder to set fire to it.—This requires being done very quickly, lest the atmospherical air should get in, and mix with the pure oxygen gas.

Emily. How beautifully it burns!

Caroline. But it is already buried in the thick vapour. This, I suppose, is sulphuric acid?

Emily. Are these acids always in a gaseous state?

Mrs. B. Sulphureous acid, as we have already observed, is a permanent gas, and can be obtained in a liquid form only by condensing it in water. In its pure state, the sulphureous acid is invisible, and it now appears in the form of a white smoke, from its combining with the moisture. But the vapour of sulphuric acid, which you have just seen to rise during the combustion, is not a gas, but only a vapour, which condenses into liquid sulphuric acid, by losing its caloric. But it appears from Sir H. Davy's experiments, that this formation and condensation of sulphuric acid requires the presence of water, for which purpose the vapour is received into cold water which may afterwards be separated from the acid by evaporation.

Sulphur has hitherto been considered as a simple substance; but Sir H. Davy has suspected that it contains a small portion of hydrogen, and perhaps also of oxygen.

On submitting sulphur to the action of the Voltaic battery, he observed that the negative wire gave out hydrogen; and the existence of hydrogen in sulphur was rendered still more probable by his observing that a small quantity of water was produced during the combustion of sulphur.

Emily. And pray of what nature is sulphur when perfectly pure?

Mrs. B. Sulphur has probably never been obtained perfectly free from combination, so that its radical may possibly possess properties very different from those of common sulphur. It has been suspected to be of a metallic nature; but this is mere conjecture.

Before we quit the subject of sulphur, I must tell you that it is susceptible of combining with a great variety of substances, and especially with hydrogen, with which you are already acquainted. Hydrogen gas can dissolve a small portion of it.

Emily. What! can a gas dissolve a solid substance?

Mrs. B. Yes; a solid substance may be so minutely divided by heat, as to become soluble in gas: and there are several instances of it. But you must observe, that, in this case, a chemical union or combination of the sulphur with the hydrogen gas is produced. In order to effect this, the sulphur must be strongly heated in contact with the gas; the heat reduces the sulphur to such a state of extreme division, and diffuses it so thoroughly through the gas, that they combine and incorporate together. And as a proof that there must be a chemical union between the sulphur and the gas, it is sufficient to remark that they are not separated when the sulphur loses the caloric by which it was volatilized. Besides, it is evident, from the peculiar fetid smell of this gas, that it is a new compound totally different from either of its constituents; it is called *sulphuretted hydrogen gas*, and is contained in great abundance in sulphureous mineral waters.

Caroline. Are not the Harrogate waters of this nature?

Mrs. B. Yes; they are naturally impregnated with sulphuretted hydrogen gas, and there are many other springs of the same kind, which shows that this gas must often be formed in the bowels of the earth by spontaneous processes of nature.

Caroline. And could not such waters be made artificially by impregnating common water with this gas?

Mrs. B. Yes; they can be so well imitated, as perfectly to resemble the Harrogate waters.

Sulphur combines likewise with phosphorus, and with the alkalies, and alkaline earths, substances with which you are yet unacquainted. We cannot, therefore, enter into these combinations at present. In our next lesson we shall treat of phosphorus.

Emily. May we not begin that subject to-day; this lesson has been so short?

Mrs. B. I have no objection, if you are not tired. What do you say, Caroline?

Caroline. I am as desirous as Emily of prolonging the lesson to-day, especially as we are to enter on a new subject; for I confess that sulphur has not appeared to me so interesting as the other simple bodies.

Mrs. B. Perhaps you may find phosphorus more entertaining. You must not, however, be discouraged when you meet with some parts of a study less amusing than others; it would answer no good purpose to select the most pleasing parts, since, if we did not proceed with some method, in order to acquire a general idea of the whole, we could scarcely expect to take interest in any particular subjects.

PHOSPHORUS.

Phosphorus is considered as a simple body; though, like sulphur, it has been suspected of containing hydrogen. It was not known by the earlier chemists. It was first discovered by Brandt, a chemist of Hamburgh, whilst employed in researches after the philosopher's stone; but the method of obtaining it remained a secret till it was a second time discovered both by Kunckel and Boyle, in the year 1680. You see a specimen of phosphorus in this phial; it is generally moulded into small sticks of a yellowish colour, as you find it here.

Caroline. I do not understand in what the discovery consisted; there may be a secret method of making an artificial composition, but how can you talk of *making* a substance which naturally exists?

Mrs. B. A body may exist in nature so closely combined with other substances, as to elude the observation of chemists, or render it extremely difficult to obtain it in its separate state. This is the case with phosphorus, which is always so intimately combined with other substances, that its existence remained unnoticed till Brandt discovered the means of obtaining it free from other combinations. It is found in all animal substances, and is now chiefly extracted from bones, by a chemical process. It exists also in some plants, that bear a strong analogy to animal matter in their chemical composition.

Emily. But is it never found in its pure separate state?

Mrs. B. Never, and this is the reason that it remained so long undiscovered.

Phosphorus is eminently combustible; it melts and takes fire at the temperature of one hundred degrees, and absorbs in its combustion nearly once and a half its own weight of oxygen.

Caroline. What! will a pound of phosphorus consume a pound and a half of oxygen?

Mrs. B. So it appears from accurate experiments. I can show you with what violence it combines with oxygen, by burning some of it in that gas. We must manage the experiment in the same manner as we did the combustion of sulphur. You see I am obliged to cut this little bit of phosphorus under water, otherwise there would be danger of its taking fire by the heat of my fingers. I now put it into the receiver, and kindle it by means of a hot wire.

Emily. What a blaze! I can hardly look at it. I never saw any thing so brilliant, Does it not hurt your eyes, Caroline?

Caroline. Yes; but still I cannot help looking at it. A prodigious quantity of oxygen must indeed be absorbed, when so much light and caloric are disengaged!

Mrs. B. In the combustion of a pound of phosphorus, a sufficient quantity of caloric is set free to melt upwards of a hundred pounds of ice; this has been computed by direct experiments with the calorimeter.

Emily. And is the result of this combustion, like that of sulphur, an acid?

Mrs. B. Yes; phosphoric acid. And had we duly proportioned the phosphorus and the oxygen, they would have been completely converted into phosphoric acid, weighing together, in this new state, exactly the sum of their weights separately. The water would have ascended into the receiver, on account of the vacuum formed, and would have filled it entirely. In this case, as in the combustion of sulphur, the acid vapour formed is absorbed and condensed in the water of the receiver. But when this combustion is performed without any water or moisture being present, the acid then appears in the form of concrete whitish flakes, which are, however, extremely ready to melt upon the least admission of moisture.

Emily. Does phosphorus, in burning in atmospherical air, produce, like sulphur, a weaker sort of the same acid?

Mrs. B. No: for it burns in atmospherical air, nearly at the same temperature as in pure oxygen gas; and it is in both cases so strongly disposed to combine with the oxygen, that the combustion is perfect, and the product similar; only in atmospherical air, being less rapidly supplied with oxygen, the process is performed in a slow manner.

Caroline. But is there no method of acidifying phosphorus in a slighter manner, so as to form *phosphorous* acid?

Mrs. B. Yes, there is. When simply exposed to the atmosphere, phosphorus undergoes a kind of slow combustion at any temperature above zero.

Emily. Is not the process in this case rather an oxydation than a combustion? For if the oxygen is too slowly absorbed for a sensible quantity of light and heat to be disengaged, it is not a true combustion.

Mrs. B. The case is not as you suppose: a faint light is emitted which is very discernible in the dark; but the heat evolved is not sufficiently strong to be sensible; a whitish vapour arises from this combustion, which, uniting with water, condenses into liquid phosphorus acid.

Caroline. Is it not very singular that phosphorus should burn at so low a temperature in atmospherical air, whilst it does not burn in pure oxygen without the application of heat?

Mrs. B. So it at first appears. But this circumstance seems to be owing to the nitrogen gas of the atmosphere. This gas dissolves small particles of phosphorus, which being thus minutely divided and diffused in the atmospherical air, combines with the oxygen, and undergoes this slow combustion. But the same effect does not take place in oxygen gas, because it is not capable of dissolving phosphorus; it is therefore necessary, in this case, that heat should be applied to effect that division of particles, which, in the former instance, is produced by the nitrogen.

Emily. I have seen letters written with phosphorus, which are invisible by day-light, but may be read in the dark by their own light. They look as if they were written with fire; yet they do not seem to burn.

Mrs. B. But they do really burn; for it is by their slow combustion that the light is emitted; and phosphorus acid is the result of this combustion.

Phosphorus is sometimes used as a test to estimate the purity of atmospherical air. For this purpose, it is burnt in a graduated tube, called an *Eudiometer* (PLATE XI. fig. 2.), and from the quantity of air which the phosphorus absorbs, the proportion of oxygen in the air examined is deduced; for the phosphorus will absorb all the oxygen, and the nitrogen alone will remain.

Emily. And the more oxygen is contained in the atmosphere, the purer, I suppose, it is esteemed?

Mrs. B. Certainly. Phosphorus, when melted, combines with a great variety of substances. With sulphur it forms a compound so extremely combustible, that it immediately takes fire on coming in contact with the air. It is with this composition that phosphoric matches are prepared, which kindle as soon as they are taken out of their case and are exposed to the air.

Emily. I have a box of these curious matches; but I have observed, that in very cold weather, they will not take fire without being previously rubbed.

Mrs. B. By rubbing them you raise their temperature; for, you know, friction is one of the means of extricating heat.

Emily. Will phosphorus combine with hydrogen gas, as sulphur does?

Mrs. B. Yes; and the compound gas which results from this combination has a smell still more fetid than the sulphuretted hydrogen; it resembles that of garlic.

The *phosphoretted hydrogen gas* has this remarkable peculiarity, that it takes fire spontaneously in the atmosphere, at any temperature. It is thus, probably, that are produced those transient flames, or flashes of light, called by the vulgar *Will-of-the-Whisp*, or more properly *Ignes fatui*, which are often seen in church-yards, and places where the putrefactions of animal matter exhale phosphorus and hydrogen gas.

Caroline. Country people, who are so much frightened by those appearances, would soon be reconciled to them, if they knew from what a simple cause they proceed.

Mrs. B. There are other combinations of phosphorus that have also very singular properties, particularly that which results from its union with lime.

Emily. Is there any name to distinguish the combination of two substances, like phosphorus and lime, neither of which are oxygen, and which cannot therefore produce either an oxyd or an acid?

Mrs. B. The names of such combinations are composed from those of their ingredients, merely from a slight change in their termination. Thus the combination of sulphur with lime is called a *sulphuret*, and that of phosphorus, *a phosphuret of lime.** This latter compound, I was going to say, has the singular property of decomposing water, merely by being thrown into it. It effects this by absorbing the oxygen of water, in consequence of which bubbles of hydrogen gas ascend, holding in solution a small quantity of phosphorus.

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* Phosphuret of lime is a very curious substance. To make it, take a thin glass tube, 6 or 8 inches long, and less than half an inch in diameter; if it is closed at one end, so much the better, but a cork will do. Near the closed end put a piece of phosphorus half an inch long. Then put in by means of a stick or wire, holding the tube horizontally, thirty or forty pieces of newly burned quick-lime, about the size of split peas, letting the lowest remain 2 or 3 inches from the phosphorus. Then stop the other end of the tube loosely, and place the part containing the quick-lime, in a bed of charcoal, so contriving it that a candle or red hot iron can be brought under the part where the phosphorus lies. Kindle a fire by means of bellows, and heat the lime red hot, without melting the phosphorus, which may be kept cool by a wet rag; when this is done, bring the hot iron or candle under the phosphorus, so as to make it pass through the quick-lime in the form of vapour. Cork up the phosphuret of lime for use. C.

Emily. These bubbles then are *phosphoretted hydrogen gas?*

Mrs. B. Yes; and they produce the singular appearance of a flash of fire issuing from the water, as the bubbles kindle and detonate on the surface of the water, at the instant that they come in contact with the atmosphere. [*If the water is warm, the experiment is more apt to succeed.* C.]

Caroline. Is not this effect nearly similar to that produced by the combination of phosphorus and sulphur, or, more properly speaking, the *phosphuret of sulphur?*

Mrs. B. Yes; but the phenomenon appears more extraordinary in this case, from the presence of water, and from the gaseous form of the combustible compound. Besides, the experiment surprises by its great simplicity. You only throw a piece of phosphuret of lime into a glass of water, and bubbles of fire will immediately issue from it.

Caroline. Cannot we try the experiment?

Mrs. B. Very easily; but we must do it in the open air; for the smell of the phosphoretted hydrogen gas is so extremely fetid, that it would be intolerable in the house. But before we leave the room, we may produce, by another process, some bubbles of the same gas, which are much less offensive.

There is in this little glass retort a solution of potash in water; I add to it a small piece of phosphorus. We must now heat the retort over the lamp, after having engaged its neck under water—You see it begins to boil; in a few minutes bubbles will appear, which take fire and detonate as they issue from the water.

Caroline. There is one—and another. How curious it is! —But I do not understand how this is produced.

Mrs. B. It is the consequence of a display of affinities too complicated, I fear, to be made perfectly intelligible to you at present.

In a few words, the reciprocal action of the potash, phosphorus, caloric, and water, are such, that some of the water is decomposed, and the hydrogen gas thereby formed carries off some minute particles of phosphorus, with which it forms phosphoretted hydrogen gas, a compound which spontaneously takes fire at almost any temperature.

Emily. What is that circular ring of smoke which slowly rises from each bubble after its detonation?

Mrs. B. It consists of water and phosphoric acid in vapour, which are produced by the combustion of hydrogen and phosphorus.

CONVERSATION IX.

ON CARBON.

Caroline. To-day, Mrs. B., I believe we are to learn the nature and properties of carbon. This substance is quite new to me; I never heard it mentioned before.

Mrs. B. Not so new as you imagine; for carbon is nothing more than charcoal in a state of purity, that is to say, unmixed with any foreign ingredients.

Caroline. But charcoal is made by art, Mrs. B., and a body consisting of one simple substance cannot be fabricated?

Mrs. B. You again confound the idea, of making a simple body, with that of separating it from a compound. The chemical processes by which a simple body is obtained in a state of purity, consist in *unmaking* the compound in which it is contained, in order to separate from it the simple substance in question. The method by which charcoal is usually obtained, is, indeed, commonly called *making* it; but, upon examination, you will find this process to consist only in separating it from other substances with which it is found combined in nature.

Carbon forms a considerable part of the solid matter of all organised bodies; but it is most abundant in the vegetable creation, and it is chiefly obtained from wood. When the oil and water (which are other constituents of vegetable matter) are evaporated, the black, porous, brittle substance that remains, is charcoal.

Caroline. But if heat be applied to the wood in order to evaporate the oil and water, will not the temperature of the charcoal be raised so as to make it burn; and if it combines with oxygen, can we any longer call it pure.

Mrs. B. I was going to say, that, in this operation, the air must be excluded.

Caroline. How then can the vapour of the oil and water fly off?

Mrs. B. In order to produce charcoal in its purest state, (which is, even then, but a less imperfect sort of carbon,) the operation should be performed in an earthen retort. Heat being applied to the body of the retort, the evaporable part of the wood will escape through its neck, into which no air can penetrate as long as the heated vapour continues to fill it. And if it be wished to collect these volatile products of the wood, this can easily be done by introducing the neck of the retort into the water-bath apparatus, with which you are acquainted. But the preparation of common charcoal, such as is used in kitchens and manufactures, is performed on a much larger scale, and by an easier and less expensive process.

Emily. I have seen the process of making common charcoal. The wood is ranged on the ground in a pile of a pyramidical form, with a fire underneath; the whole is then covered with clay, a few holes only being left open for the circulation of air.

Mrs. B. The holes are closed as soon as the wood is fairly lighted, so that the combustion is checked, or at least continues but in a very imperfect manner; but the heat produced by it is sufficient to force out and volatilize, through the earthy cover, most part of the oily and watery principles of the wood, although it cannot reduce it to ashes.

Emily. Is pure carbon as black as charcoal?

Mrs. B. The purest charcoal we can prepare is so; but chemists have never yet been able to separate it entirely from hydrogen. Sir H. Davy says, that the most perfect carbon that is prepared by art contains about five per cent of hydrogen; he is of opinion, that if we could obtain it quite free from foreign ingredients, it would be metallic, in common with other simple substances.

But there is a form in which charcoal appears, that I dare say will surprise you.—This ring, which I wear on my finger, owes its brilliancy to a small piece of carbon.

Caroline. Surely, you are jesting, Mrs. B.?

Emily. I thought your ring was diamond?

Mrs. B. It is so. But diamond is nothing more than carbon in a crystalized state.

Emily. That is astonishing! Is it possible to see two things apparently more different than diamond and charcoal?

Caroline. It is, indeed, curious to think that we adorn ourselves with jewels of charcoal!

Mrs. B. There are many other substances, consisting chiefly of carbon, that are remarkably white. Cotton, for instance, is almost wholly carbon.

Caroline. That, I own, I could never have imagined!—But pray, Mrs. B., since it is known of what substance diamond and cotton are composed, why should they not be manufactured, or imitated, by some chemical process, which would render them much cheaper, and more plentiful than the present mode of obtaining them?

Mrs. B. You might as well, my dear, propose that we should make flowers and fruit, nay, perhaps even animals, by a chemical process; for it is known of what these bodies consist, since every thing which we are acquainted with in nature is formed from the various simple substances that we have enumerated. But you must not suppose that a knowledge of the component parts of a body will in every case enable us to imitate it. It is much less difficult to decompose bodies, and discover of what materials they are made, than it is to recompose them. The first of these processes is called *analysis*, the last *synthesis*. When we are able to ascertain the nature of a substance by both these methods, so that the result of one confirms that of the other, we obtain the most complete knowledge of it that we are capable of acquiring. This is the case with water, with the atmosphere, with most of the oxyds, acids, and neutral salts, and with many other compounds. But the more complicated combinations of nature, even in the mineral kingdom, are in general beyond our reach, and any attempt to imitate organised bodies must ever prove fruitless; their formation is a secret that rests in the bosom of the Creator. You see, therefore, how vain it would be to attempt to make cotton by chemical means. But, surely, we have no reason to regret our inability in this instance, when nature has so clearly pointed out a method of obtaining it in perfection and abundance.

Caroline. I did not imagine that the principle of life could be imitated by the aid of chemistry; but it did not appear to me absurd to suppose that chemists might attain a perfect imitation of inanimate nature.

Mrs. B. They have succeeded in this point in a variety of instances; but, as you justly observe, the principle of life, or even the minute and intimate organisation of the vegetable kingdom, are secrets that have almost entirely eluded the researches of philosophers; nor do I imagine that human art will ever be capable of investigating them with complete success.

Emily. But diamond, since it consists of one simple unorganised substance, might be, one would think, perfectly imitable by art?

Mrs. B. It is sometimes as much beyond our power to obtain a simple body in a state of perfect purity, as it is to imitate a complicated combination; for the operations by which nature separates bodies are frequently as inimitable as those which she uses for their combination. This is the case with carbon; all the efforts of chemists to separate it entirely from other substances have been fruitless, and in the purest state in which it can be obtained by art, it still retains a portion of hydrogen, and probably of some other foreign ingredients. We are ignorant of the means which nature employs to crystalize it. It may probably be the work of ages, to purify, arrange, and unite the particles of carbon in the form of diamond. Here is some charcoal in the purest state we can procure it; you see that it is a very black, brittle, light, porous substance, entirely destitute of either taste or smell. Heat, without air, produces no alteration in it, as it is not volatile; but, on the contrary, it invariably remains at the bottom of the vessel after all the other parts of the vegetable are evaporated.

Emily. Yet carbon is, no doubt, combustible, since you say that charcoal would absorb oxygen if air were admitted during its preparation?

Caroline. Unquestionably. Besides, you know, Emily, how much it is used in cooking. But pray what is the reason that charcoal burns without smoke, whilst a wood fire smokes so much?

Mrs. B. Because, in the conversion of wood into charcoal, the volatile particles of the former have been evaporated.

Caroline. Yet I have frequently seen charcoal burn with flame; therefore it must, in that case, contain some hydrogen.

Mrs. B. Very true; but you should recollect that charcoal, especially that which is used for common purposes, is not perfectly pure. It generally retains some remains of the various other component parts of vegetables, and hydrogen particularly, which accounts for the flame in question.

Caroline. But what becomes of the carbon itself during its combustion?

Mrs. B. It gradually combines with the oxygen of the atmosphere, in the same way as sulphur and phosphorus, and, like those substances, it is converted into a peculiar acid, which flies off in a gaseous form. There is this difference, however, that the acid is not, in this instance, as in the two cases just mentioned, a mere condensible vapour, but a permanent elastic fluid, which always remains in the state of gas, under any pressure and at any temperature. The nature of this acid was first ascertained by Dr. Black, of Edinburgh; and, before the introduction of the new nomenclature, it was called *fixed air*. It is now distinguished by the more appropriate name of *carbonic acid gas*.

Emily. Carbon then, can be volatilized by burning, though, by heat alone, no such effect is produced?

Mrs. B. Yes; but then it is no longer simple carbon, but an acid of which carbon forms the basis. In this state, carbon retains no more apearance of solidity or coporeal form, than the basis of any other gas. And you may, I think, from this instance, derive a more clear idea of the basis of the oxygen, hydrogen, and nitrogen gases, the existence of which, as real bodies, you seemed to doubt, because they were not to be obtained simply in a solid form.

Emily. That is true; we may conceive the basis of the oxygen, and of the other gases, to be solid, heavy substances, like carbon; but so much expanded by caloric as to become invisible.

Caroline. But does not the carbonic acid gas partake of the blackness of charcoal?

Mrs. B. Not in the least. Blackness, you know, does not appear to be essential to carbon, and it is pure carbon, and not charcoal, that we must consider as the basis of carbonic acid. We shall make some carbonic acid, and, in order to hasten the process, we shall burn the carbon in oxygen gas.

Emily. But do you mean then to burn diamond?

Mrs. B. Charcoal will answer the purpose still better, being softer and more easy to inflame; besides the experiments on diamond are rather expensive.

Caroline. But is it possible to burn diamond?

Mrs. B. Yes, it is; and in order to effect this combustion, nothing more is required than to apply a sufficient degree of heat by means of the blow-pipe, and of a stream of oxygen gas. Indeed it is by burning diamond that its chemical nature has been ascertained. It has long been known as a combustible substance, but it is within these few years only that the product of its combustion has been proved to be pure carbonic acid. This remarkable discovery is due to Mr. Tennant.

Now let us try to make some carbonic acid.—Will you, Emily, decant some oxygen gas from this large jar into the receiver in which we are to burn the carbon; and I shall introduce this small piece of charcoal, with a little lighted tinder, which will be necessary to give the first impulse to the combustion.

Emily. I cannot conceive how so small a piece of tinder, and that but just lighted, can raise the temperature of the carbon sufficiently to set fire to it; for it can produce scarcely any sensible heat, and it hardly touches the carbon.

Mrs. B. The tinder thus kindled has only heat enough to begin its own combustion, which, however, soon becomes so rapid in the oxygen gas, as to raise the temperature of the charcoal sufficiently for this to burn likewise, as you see is now the case.

Emily. I am surprised that the combustion of carbon is not more brilliant; it does not give out near so much light or caloric as phosphorus, or sulphur. Yet since it combines with so much oxygen, why is not a proportional quantity of light and heat disengaged from the decomposition of the oxygen gas, and the union of its electricity with that of the charcoal ?

Mrs. B. It is not surprising that less light and heat should be liberated in this than in almost any other combustion, since the oxygen, instead of entering into a solid or liquid combination, as it does in the phosphoric and sulphuric acids, is employed in forming another elastic fluid ; it therefore parts with less of its caloric.

Emily. True ; and, on second consideration, it appears, on the contrary, surprising that the oxygen should, in its combination with carbon, retain a sufficient portion of caloric to maintain both substances in a gaseous state.

Caroline. We may then judge of the degree of solidity in which oxygen is combined in a burnt body, by the quantity of caloric liberated during its combustion ?

Mrs. B. Yes ; provided that you take into the account the quantity of oxygen absorbed by the combustible body, and observe the proportion which the caloric bears to it.

Caroline. But why should the water, after the combustion of carbon, rise in the receiver, since the gas within it retains an aëriform state ?

Mrs. B. Because the carbonic acid gas is gradually absorbed by the water ; and this effect would be promoted by shaking the receiver.

Emily. The charcoal is now extinguished, though it is not nearly consumed ; it has such an extraordinary avidity for oxygen, I suppose, that the receiver did not contain enough to satisfy the whole.

Mrs. B. That is certainly the case ; for if the combustion were performed in the exact proportions of 28 parts of carbon to 72 of oxygen, both these ingredients would disappear, and 100 parts of carbonic acid would be produced.

Caroline. Carbonic acid must be a very strong acid, since it contains so great a proportion of oxygen ?

Mrs. B. That is a very natural inference ; yet it is erroneous. For the carbonic is the weakest of all the acids. The strength of an acid seems to depend upon the nature of its basis, and its mode of combination, as well as upon the proportion of the acidifying principle. The same quantity of oxygen that will convert some bodies into strong acids, will only be sufficient simply to oxydate others.

Caroline. Since this acid is so weak, I think chemists should have called it the *carbonous*, instead of the *carbonic* acid.

Emily. But, I suppose, the carbonous acid is still weaker, and is formed by burning carbon in atmospherical air.

Mrs. B. It has been lately discovered, that carbon may be converted into a gas, by uniting with a smaller proportion of oxygen; but as this gas does not possess any acid properties, it is no more than an oxyd; it is called *gaseous oxyd of carbon.*

Caroline. Pray is not carbonic acid a very wholesome gas to breathe, as it contains so much oxygen?

Mrs. B. On the contrary, it is extremely pernicious. Oxygen, when in a state of combination with other substances, loses, in almost every instance, its respirable properties, and the salubrious effects which it has on the animal economy when in its unconfined state. Carbonic acid is not only unfit for respiration, but extremely deleterious if taken into the lungs.

Emily. You know, Caroline, how very unwholesome the fumes of burning charcoal are reckoned.

Caroline. Yes; but to confess the truth, I did not consider that a charcoal fire produced carbonic acid gas.—Can this gas be condensed into a liquid?

Mrs. B. No: for, as I told you before, it is a permanent elastic fluid. But water can absorb a certain quantity of this gas, and can even be impregnated with it, in a very strong degree, by the assistance of agitation and pressure, as I am going to show you. I shall decant some carbonic acid gas into this bottle, which I fill first with water, in order to exclude the atmospherical air; the gas is then introduced through the water, which you see it displaces, for it will not mix with it in any quantity, unless strongly agitated, or allowed to stand over it for some time. The bottle is now about half full of carbonic acid gas, and the other half is still occupied by the water. By corking the bottle, and then violently shaking it, in this way, I can mix the gas and water together.—Now will you taste it?

Emily. It has a distinct acid taste.

Caroline. Yes, it is sensibly sour, and appears full of little bubbles.

Mrs. B. It possesses likewise all the other properties of acids, but of course, in a less degree than the pure carbonic acid gas, as it is so much diluted by water.

This is a kind of artificial Seltzer water. By analysing that which is produced by nature, it was found to contain scarcely any thing more than common water impregnated with a certain proportion of carbonic acid gas. We are, therefore, able to imitate it, by mixing those proportions of water and carbonic acid. Here, my dear, is an instance in which, by a chemical process, we can exactly copy the operations of nature; for the artificial Seltzer waters can be made in every respect similar to those of nature; in one point, indeed, the former have an advantage, since they may be prepared stronger or weaker, as occasion requires.

Caroline. I thought I had tasted such water before. But what renders it so brisk and sparkling?

Mrs. B. This sparkling, or effervescence, as it is called, is always occasioned by the action of an elastic fluid escaping from a liquid; in the artificial Seltzer water, it is produced by the carbonic acid, which being lighter than the water in which it was strongly condensed, flies off with great rapidity the instant the bottle is uncorked; this makes it necessary to drink it immediately. The bubbling that took place in this bottle was but trifling, as the water was but very slightly impregnated with carbonic acid. It requires a particular apparatus to prepare the gaseous artificial mineral waters.

Emily. If, then, a bottle of Seltzer water remains for any length of time uncorked, I suppose it returns to the state of common water?

Mrs. B. The whole of the carbonic acid gas, or very nearly so, will soon disappear; but there is likewise in Seltzer water a very small quantity of soda, and of a few other saline or earthy ingredient, which will remain in the water, though it should be kept uncorked for any length of time.

Caroline. I have often heard of people drinking soda water. Pray what sort of water is that?

Mrs. B. It is a kind of artificial Seltzer water, holding in solution, besides the gaseous acid, a particular saline substance, called soda, which imparts to the water certain medicinal qualities.

Caroline. But how can these waters be so wholesome, since carbonic acid is so pernicious?

Mrs. B. A gas, we may conceive, though very prejudical to breathe, may be beneficial to the stomach.—But it would be of no use to attempt explaining this more fully at present.

Caroline. Are waters never impregnated with other gases?

Mrs. B. Yes; there are several kinds of gaseous waters. I forgot to tell you that waters have, for some years past, been prepared, impregnated both with oxygen and hydrogen gases. These are not an imitation of nature, but are altogether obtained by artificial means. They have been lately used medicinally, particularly on the continent, where, I understand, they have acquired some reputation.

Emily. If I recollect right, Mrs. B., you told us that carbon was capable of decomposing water; the affinity between oxygen and carbon must, therefore, be greater than between oxygen and hydrogen?

Mrs. B. Yes; but this is not the case unless their temperature be raised to a certain degree. It is only when carbon is red-hot, that it is capable of separating the oxygen from the hydrogen. Thus, if a small quantity of water be thrown on a red-hot fire, it will increase rather than extinguish the combustion; for the coals or wood, (both of which contain a quantity of carbon,) decompose the water, and thus supply the fire both with oxygen and hydrogen gases. If, on the contrary, a large mass of water be thrown over the fire, the diminution of heat thus produced is such, that the combustible matter loses the power of decomposing the water, and the fire is extinguished.

Emily. I have heard that fire-engines sometimes do more harm than good, and that they actually increase the fire when they cannot throw water enough to extinguish it. It must be owing, no doubt, to the decomposition of the water by the carbon during the conflagration.

Mrs. B. Certainly.—The apparatus which you see here (PLATE XI. fig. 3.), may be used to exemplify what we have just said. It consists in a kind of open furnace, through which a porcelain tube, containing charcoal, passes. To one end of the tube is adapted a glass retort with water in it; and the other end communicates with a receiver placed on the water-bath. A lamp being applied to the retort, and the water made to boil, the vapour is gradually conveyed through the red hot charcoal, by which it is decomposed; and the hydrogen gas which results from this decomposition is collected in the receiver. But the hydrogen thus obtained is far from being pure; it retains in solution a minute portion of carbon, and contains also a quantity of carbonic acid. This renders it heavier than pure hydrogen gas, and gives it some peculiar properties; it is distinguished by the name of *carbonated hydrogen gas.*

Caroline. And whence does it obtain the carbonic acid that is mixed with it?

Emily. I believe I can answer that question, Caroline.—From the union of the oxygen (proceeding from the decomposed water) with the carbon, which, you know, makes carbonic acid.

Caroline. True; I should have recollected that.—The product of the decomposition of water by red-hot charcoal, therefore, is carbonated hydrogen gas, and carbonic acid gas.

Mrs. B. You are perfectly right now.

Carbon is frequently found combined with hydrogen in a state of solidity, especially in coals, which owe their combustible nature to these two principles.

Emily. Is it the hydrogen, then, that produces the flame of coals?

Mrs. B. It is so; and when all the hydrogen is consumed, the carbon continues to burn without flame. But again, as I mentioned when speaking of the gas-lights, the hydrogen gas produced by the burning of coals is not pure: for, during the combustion, particles of carbon are successively volatilized with the hydrogen, with which they form what is called a *hydro-carbonat*, which is the principal product of this combustion.

Carbon is a very bad conductor of heat; for this reason, it is employed (in conjunction with other ingredients) for coating furnaces and other chemical apparatus.

Emily. Pray what is the use of coating furnaces?

Mrs. B. In most cases, in which a furnace is used, it is necessary to produce and preserve a great degree of heat, for which purpose every possible means are used to prevent the heat from escaping by communicating with other bodies, and this object is attained by coating over the inside of the furnace with a kind of plaster, composed of materials that are bad conductors of heat.

Carbon, combined with a small quantity of iron, forms a compound called plumbago, or black-lead, of which pencils are made. This substance, agreeably to the nomenclature, is *a carburet of iron.*

Emily. Why, then, is it called black-lead?

Mrs. B. It is an ancient name given to it by ignorant people, from its shining metallic appearance; but it is certainly a most improper name for it, as there is not a particle of lead in the composition. There is only one mine of this mineral, which is in Cumberland.* It is supposed to approach as nearly to pure carbon as the best prepared charcoal does, as it contains only five parts of iron, unadulterated by any other foreign ingredients. There is another carburet of iron, in which the iron, though united only to an extremely small proportion of carbon, acquires very remarkable properties; this is steel.

Caroline. Really; and yet steel is much harder than iron?

Mrs. B. But carbon is not ductile like iron, and therefore may render the steel more brittle, and prevent its bending so easily. Whether it is that the carbon, by introducing itself into the pores of the iron, and, by filling them, makes the metal both harder and heavier; or whether this change depends upon some chemical cause, I cannot pretend to decide. But there is a subsequent operation, by which the hardness of steel is very much increased, which simply consists in heating the steel till it is red-hot, and then plunging it into cold water.

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* She means in England. Black lead is found in a great variety of places in this country. C.

Carbon, besides the combination just mentioned, enters into the composition of a vast number of natural productions, such, for instance, as all the various kinds of oils, which result from the combination of carbon, hydrogen, and caloric, in various proportions.

Emily. I thought that carbon, hydrogen, and caloric, formed carbonated hydrogen gas?

Mrs. B. That is the case when a small portion of carbonic acid gas is held in solution by hydrogen gas. Different proportions of the same principles, together with the circumstances of their union, produce very different combinations; of this you will see innumerable examples. Besides, we are not now talking of gases, but of carbon and hydrogen, combined only with a quantity of caloric, sufficient to bring them to the consistency of oil or fat.

Caroline. But oil and fat are not of the same consistence?

Mrs. B. Fat is only congealed oil; or oil, melted fat. The one requires a little more heat to maintain it in a fluid state than the other. Have you never observed the fat of meat turned to oil by the caloric it has imbibed from the fire?

Emily. Yet oils in general, as salad-oil, and lamp-oil, do not turn to fat when cold?

Mrs. B. Not at the common temperature of the atmosphere, because they retain too much caloric to congeal at that temperature; but if exposed to a sufficient degree of cold, their latent heat is extricated, and they become solid fat substances. Have you never seen salad-oil frozen in winter?

Emily. Yes; but it appears to me in that state very different from animal fat.

Mrs. B. The essential constituent parts of either vegetable or animal oils are the same, carbon and hydrogen; their variety arises from the different proportions of these substances, and from other accessory ingredients that may be mixed with them. The oil of a whale, and the oil of roses, are, in their essential constituent parts, the same; but the one is impregnated with the offensive particles of animal matter, the other with the delicate perfume of a flower.

The difference of *fixed oils*, and *volatile* or *essential oils*, consists also in the various proportions of carbon and hydrogen. Fixed oils are those which will not evaporate without being decomposed; this is the case with all common oils, which contain a greater proportion of carbon than the essential oils. The essential oils (which comprehend the whole class of essences and perfumes) are lighter; they contain more equal proportions of carbon and hydrogen, and are volatilized or evaporated without being decomposed.

Emily. When you say that one kind of oil will evaporate, and the other be decomposed, you mean, I suppose, by the application of heat?

Mrs. B. Not necessarily; for there are oils that will evaporate slowly at the common temperature of the atmosphere; but for a more rapid volatilization, or for their decomposition, the assistance of heat is required.*

Caroline. I shall now remember, I think, that fat and oil are really the same substances, both consisting of carbon and hydrogen; that in fixed oils the carbon preponderates, and heat produces a decomposition; while, in essential oils, the proportion of hydrogen is greater, and heat produces a volatilization only.

Emily. I suppose the reason why oil burns so well in lamps is because its two constituents are so combustible?

Mrs. B. Certainly; the combustion of oil is just the same as that of a candle; if tallow, it is only oil in a concrete state; if wax, or spermaceti, its chief chemical ingredients are still hydrogen and carbon.

Emily. I wonder, then, there should be so great a difference between tallow and wax?

Mrs. B. I must again repeat, that the same substances, in different proportions, produce results that have sometimes scarcely any resemblance to each other. But this is rather a general remark that I wish to impress upon your minds, than one which is applicable to the present case; for tallow and wax are far from being very dissimilar; the chief difference consists in the wax being a purer compound of carbon and hydrogen than the tallow, which retains more of the gross particles of animal matter. The combustion of a candle, and that of a lamp, both produce water and carbonic acid gas. Can you tell me how these are formed?

Emily. Let me reflect .... Both the candle and lamp burn by means of fixed oil—this is decomposed as the combustion goes on; and the constituent parts of the oil being thus separated, the carbon unites with a portion of oxygen from the atmosphere to form carbonic acid gas, whilst the hydrogen combines with another portion of oxygen, and forms with it water. The products, therefore, of the combustion of oils are water and carbonic acid gas.

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* The volatile or essential oils evaporate when exposed to the air. Hence the odor which oil or lavender, peppermint, &c. give out. The animal oils, and what are called *expressed* oils, as that of castor, &c. do not evaporate. Hence a good test of the purity of essential oil, is, to let a drop fall on paper. If a grease-spot remains after a few minutes, it is adulterated with some fixed oil. C.

Caroline. But we see neither water nor carbonic acid produced by the combustion of a candle.

Mrs. B. The carbonic acid gas, you know, is invisible, and the water being in a state of vapour, is so likewise. Emily is perfectly correct in her explanation, and I am very much pleased with it.

All the vegetable acids consist of various proportions of carbon and hydrogen, acidified by oxygen. Gums, sugar, and starch, are likewise composed of these ingredients; but, as the oxygen which they contain is not sufficient to convert them into acids, they are classed with the oxyds, and called vegetable oxyds.

Caroline. I am very much delighted with all these new ideas; but, at the same time, I cannot help being apprehensive that I may forget many of them.

Mrs. B. I would advise you to take notes, or, what would answer better still, to write down, after every lesson, as much of it as you can recollect. And, in order to give you a little assistance, I shall lend you the heads or index, which I occasionally consult for the sake of preserving some method and arrangement in these conversations. Unless you follow some such plan, you cannot expect to retain nearly all that you learn, how great soever be the impression it may make on you at first.

Emily. I will certainly follow your advice.—Hitherto I have found that I recollected pretty well what you have taught us; but the history of carbon is a more extensive subject than any of the simple bodies we have yet examined.

Mrs. B. I have little more to say on carbon at present; but hereafter you will see that it performs a considerable part in most chemical operations.

Caroline. That is, I suppose, owing to its entering into the composition of so great a variety of substances?

Mrs. B. Certainly; it is the basis, you have seen, of all vegetable matter; and you will find that it is very essential to the process of animalization. But in the mineral kingdom also, particularly in its form of carbonic acid, we shall often discover it combined with a great variety of substances.

In chemical operations, carbon is particularly useful, from its very great attraction for oxygen, as it will absorb this substance from many oxygenated or burnt bodies, and thus deoxygenate, or *unburn* them, and restore them to their original combustible state.

Caroline. I do not understand how a body can be *unburnt*, and restored to its original state. This piece of tinder, for instance, that has been burnt, if by any means the oxygen were extracted from it, would not be restored to its former state of linen; for its texture is destroyed by burning, and that must be the case with all organized or manufactured substances, as you observed in a former conversation.

Mrs. B. A compound body is decomposed by combustion in a way which generally precludes the possibility of restoring it to its former state; the oxygen, for instance, does not become fixed in the tinder, but it combines with its volatile parts, and flies off in the shape of gas, or watery vapour. You see, therefore, how vain it would be to attempt the recomposition of such bodies. But, with regard to simple bodies, or at least bodies whose component parts are not distributed by the process of oxygenation or deoxygenation, it is often possible to restore them, after combustion, to their original state.—The metals, for instance, undergo no other alteration by combustion than a combination with oxygen; therefore, when the oxygen is taken from them, they return to their pure metallic state. But I shall say nothing further of this at present, as the metals will furnish ample subject for another morning; and they are the class of simple bodies that come next under consideration.

CONVERSATION X.

ON METALS.

Mrs. B. THE METALS, which we are now to examine, are bodies of a very different nature from those which we have hitherto considered. They do not, like the bases of gases, elude the immediate observation of our senses; for they are the most brilliant, the most ponderous, and the most palpable substances in nature.

Caroline. I doubt, however, whether the metals will appear to us so interesting, and give us so much entertainment as those mysterious elements which conceal themselves from our view. Besides, they cannot afford so much novelty; they are bodies with which we are already so well acquainted.

Mrs. B. You are not aware, my dear, of the interesting discoveries which were a few years ago made by Sir H. Davy respecting this class of bodies. By the aid of the Voltaic battery, he has obtained from a variety of substances, metals before unknown, the properties of which are equally new and curious. We shall begin, however, by noticing those metals with which you profess to be so well acquainted. But the acquaintance, you will soon perceive, is but very superficial; and I trust that you will find both novelty and entertainment in considering the metals in a chemical point of view. To treat of this subject fully, would require a whole course of lectures; for metals form of themselves a most important branch of practical chemistry. We must, therefore, confine ourselves to a general view of them. These bodies are seldom found naturally in their metallic form; they are generally more or less oxygenated or combined with sulphur, earths, or acids, and are often blended with each other. They are found buried in the bowels of the earth in most parts of the world, but chiefly in mountainous districts, where the surface of the globe has been disturbed by earthquakes, volcanoes, and other convulsions of nature. They are spread in strata or beds, called veins, and these veins are composed of a certain quantity of metal, combined with various earthy substances, with which they form minerals of different nature and appearance, which are called *ores*.

Caroline. I now feel quite at home, for my father has a lead-mine in Yorkshire, and I have heard a great deal about veins of ore, and of the *roasting* and *smelting* of the lead; but, I confess, that I do not understand in what these operations consist.

Mrs. B. Roasting is the process by which the volatile parts of the ore are evaporated; smelting, that by which the pure metal is afterwards separated from the earthy remains of the ore. This is done by throwing the whole into a furnace, and mixing with it certain substances that will combine with the earthy parts and other foreign ingredients of the ore; the metal being the heaviest, falls to the bottom, and runs out by proper openings in its pure metallic state.

Emily. You told us in a preceding lesson that metals had a great affinity for oxygen. Do they not, therefore, combine with oxygen, when strongly heated in the furnace, and run out in the state of oxyds?

Mrs. B. No; for the scoriæ, or oxyd, which soon forms on the surface of the fused metal, when it is oxydable, prevents the air from having any farther influence on the mass; so that neither combustion nor oxygenation can take place.

Caroline. Are all the metals equally combustible?

Mrs. B. No; their attraction for oxygen varies extremely. There are some that will combine with it only at a very high temperature, or by the assistance of acids; whilst there are others that oxydate spontaneously and with great rapidity, even at the lowest temperature; such is in particular manganese, which scarcely ever exists in the metallic state, as it immediately absorbs oxygen on being exposed to the air, and crumbles to an oxyd in the course of a few hours.

Emily. Is not that the oxyd from which you extracted the oxygen gas?

Mrs. B. It is: so that, you see, this metal attracts oxygen at a low temperature, and parts with it when strongly heated.

Emily. Is there any other metal that oxydates at the temperature of the atmosphere?

Mrs. B. They all do, more or less, excepting gold, silver, and platina.

Copper, lead, and iron, oxydate slowly in the air, and cover themselves with a sort of rust, a process which depends on the gradual conversion of the surface into an oxyd. This rusty surface preserves the interior metal from oxydation, as it prevents the air from coming in contact with it. Strictly speaking, however, the word rust applies only to the oxyd, which forms on the surface of iron, when exposed to air and moisture, which oxyd appears to be united with a small portion of carbonic acid.

Emily. When metals oxydate from the atmosphere without an elevation of temperature, some light and heat, I suppose, must be disengaged, though not in sufficient quantities to be sensible.

Mrs. B. Undoubtedly; and, indeed, it is not surprising that in this case the light and heat should not be sensible, when you consider how extremely slow, and, indeed, how imperfectly, most metals oxydate by mere exposure to the atmosphere. For the quantity of oxygen with which metals are capable of combining, generally depends upon their temperature; and the absorption stops at various points of oxydation, according to the degree to which their temperature is raised.

Emily. That seems very natural; for the greater the quantity of caloric introduced into a metal, the more will its positive electricity be exalted, and consequently the stronger will be its affinity for oxygen.

Mrs. B. Certainly. When the metal oxygenates with sufficient rapidity for light and heat to become sensible, combustion actually takes place. But this happens only at very high temperatures, and the product is nevertheless an oxyd; for though, as I have just said, metals will combine with different proportions of oxygen, yet with the exception of only five of them, they are not susceptible of acidification.

Metals change colour during the different degrees of oxydation which they undergo. Lead, when heated in contact with the atmosphere, first becomes grey; if its temperature be then raised, it turns yellow, and a still stronger heat changes it to red. Iron becomes successively a green, brown, and white oxyd. Copper changes from brown to blue, and lastly green.

Emily. Pray, is the white lead with which houses are painted prepared by oxydating lead?

Mrs. B. Not merely by oxydating, but by being also united with carbonic acid. It is a carbonat of lead. The mere oxyd of lead is called red lead. Litharge is another oxyd of lead, containing less oxygen. Almost all the metallic oxyds are used as paints. The various sorts of ochres consist chiefly of iron more or less oxydated. And it is a remarkable circumstance, that if you burn metals rapidly, the light or flame they emit during combustion partakes of the colours which the oxyd successively assumes.

Caroline. How is that accounted for, Mrs. B., since light does not proceed from the burning body, but from the decomposition of the oxygen gas?

Mrs. B. The correspondence of the colour of the light with that of the oxyd which emits it, is, in all probability, owing to some particles of the metal which are volatilised and carried off by the caloric.

Caroline. It is then a sort of metallic gas.

Why is it reckoned so unwholsome to breathe the air of a place in which metals are melting?

Mrs. B. Perhaps the notion is too generally entertained. But it is true with respect to lead, and some other noxious metals, because, unless care be taken, the particles of the oxyd which are volatilized by the heat, are inhaled in with the breath, and may produce dangerous effects.

I must show you some instances of the combustion of metals; it would require the heat of a furnace to make them burn in the common air, but if we supply them with a stream of oxygen gas, we may easily accomplish it.

Caroline. But it will still, I suppose, be necessary in some degree to raise their temperature?

Mrs. B. This, as you shall see, is very easily done, particularly if the experiment be tried upon a small scale.—I begin by lighting this piece of charcoal with the candle, and then in-

PLATE XII.

Apparatus for the combustion of
metals by means of oxygen gas

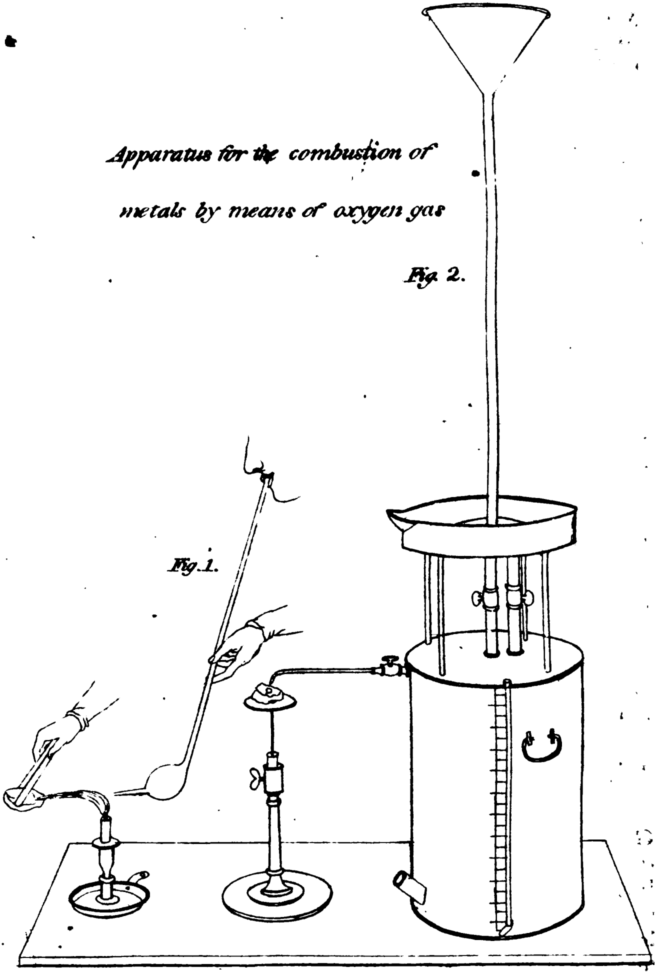
Fig. 2.

Fig. 1.

Fig 1 Igniting charcoal with a taper & blow-pipe. Fig. 2. Combustion of metals by means of a blow-pipe conveying a stream of oxygen gas from a gas holder.

crease the rapidity of its combustion by blowing upon it with a blow-pipe. (PLATE XII. fig. 1.)

Emily. That I do not understand; for it is not every kind of air, but merely oxygen gas, that produces combustion. Now you said that in breathing we inspired, but did not expire oxygen gas. Why, therefore, should the air which you breathe through the blow-pipe promote the combustion of the charcoal?

Mrs. B. Because the air, which has but once passed through the lungs, is yet but little altered, a small portion only of its oxygen being destroyed; so that a great deal more is gained by increasing the rapidity of the current, by means of the blow-pipe, than is lost in consequence of the air passing once through the lungs, as you shall see —

Emily. Yes, indeed, it makes the charcoal burn much brighter.

Mrs. B. Whilst it is red-hot, I shall drop some iron filings on it, and supply them with a current of oxygen gas, by means of this apparatus, (PLATE XII. fig. 2.) which consists simply of a closed tin cylindrical vessel, full of oxygen gas, with two apertures and stop-cocks, by one of which a stream of water is thrown into the vessel through a long funnel, whilst by the other the gas is forced out through a blow-pipe adapted to it, as the water gains admittance.—Now that I pour water into the funnel, you may hear the gas issuing from the blow-pipe—I bring the charcoal close to the current, and drop the filings upon it —

Caroline. They emit much the same vivid light as the combustion of the iron wire in oxygen gas.

Mrs. B. The process is, in fact, the same; there is only some difference in the mode of conducting it. Let us burn some tin in the same manner—you see that it is equally combustible.—Let us now try some copper—

Caroline. This burns with a greenish flame; it is, I suppose, owing to the colour of the oxyd?

Emily. Pray, shall we not also burn some gold?

Mrs. B. That is not in our power, at least in this way.—Gold, Silver, and platina, are incapable of being oxydated by the greatest heat that we can produce by the common method. It is from this circumstance, that they have been called perfect metals. Even these, however, have an affinity for oxygen; but their oxydation or combustion can be performed only by means of acids or by electricity.

The spark given out by the Voltaic battery produces at the point of contact a greater degree of heat than any other process; and it is at this very high temperature only that the affinity of these metals for oxygen will enable them to act on each other.

I am sorry that I cannot show you the combustion of the perfect metals by this process, but it requires a considerable Voltaic battery. You will see these experiments performed in the most perfect manner, when you attend the chemical lectures of the Royal Institution. But in the mean time I can, without difficulty, show you an ingenious apparatus lately contrived for the purpose of producing intense heats, the power of which nearly equals that of the largest Voltaic batteries. It simply consists, you see, in a strong box, made of iron or copper, PLATE X. fig. 2.) to which may be adapted this air-syringe or condensing-pump, and a stop-cock terminating in a small orifice similar to that of a blow-pipe. By working the condensing syringe, up and down in this manner, a quantity of air is accumulated in the vessel, which may be increased to almost any extent; so that if we now turn the stop-cock, the condensed air will rush out, forming a jet of considerable force; and if we place the flame of a lamp in the current, you will see how violently the flame is driven in that direction.

Caroline. It seems to be exactly the same effect as that of a blow-pipe worked by the mouth, only much stronger.

Emily. Yes; and this new instrument has this additional advantage, that it does not fatigue the mouth and lungs like the common blow-pipe, and requires no art in blowing.

Mrs. B. Unquestionably; but yet this blow-pipe would be of very limited utility, if its energy and power could not be greatly increased by some other contrivance. Can you imagine any mode of producing such an effect?

Emily. Could not the reservoir be charged with pure oxygen, instead of common air, as in the case of the gas-holder?

Mrs. B. Undoubtedly; and this is precisely the contrivance I allude to. The vessel need only be supplied with air from a bladder full of oxygen, instead of the air of the room, and this, you see, may be easily done by screwing the bladder on the upper part of the syringe, so that in working the syringe the oxygen gas is forced from the bladder into the condensing vessel.

Caroline. With the aid of this small apparatus, therefore, we could obtain the same effects as those we have just produced with the gas-holder, by means of a column of water forcing the gas out of it?

Mrs. B. Yes; and much more conveniently so. But there is a mode of using this apparatus by which more powerful effects still may be obtained. It consists in condensing in the reservoir, not oxygen alone, but a mixture of oxygen and hydrogen in the exact proportion in which they unite to produce water; and then kindling the jet formed by the mixed gases. The heat disengaged by this combustion, without the help of any lamp, is probably the most intense of any known; and various effects are said to have been obtained from it which exceed all expectation.

Caroline. But why should we not try this experiment?

Mrs. B. Because it is not exempt from danger;* the combustion (notwitstanding various contrivances which have been resorted to with a view to prevent accident) being apt to penetrate into the inside of the vessel, and to produce a dangerous and violent explosion. We shall, therefore, now proceed in our subject.

Caroline. I think you said the oxyds of metals could be restored to their metallic state?

Mrs. B. Yes; this is called *reviving* a metal. Metals are in general capable of being revived by charcoal, when heated red hot, charcoal having a greater attraction for oxygen than the metals. You need only, therefore, decompose, or unburn the oxyd, by depriving it of its oxygen, and the metal will be restored to its pure state.

Emily. But will the carbon, by this operation, be burnt, and be converted into carbonic acid?

Mrs. B. Certainly. There are other combustible substances to which metals at a high temperature will part with their oxygen. They will also yield it to each other, according to their several degrees of attraction for it; and if the oxygen goes into a more dense state in the metal which it enters, than it existed in that in which it quits, a proportional disengagement of caloric will take place.

Caroline. And cannot the oxyds of gold, silver, and platina, which are formed by means of acids or of the electric fluid, be restored to their metallic state?

Mrs. B. Yes, they may; and the intervention of a combustible body is not required; heat alone will take the oxygen from them, convert it into a gas, and revive the metal.

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* Hydrogen and oxygen may be burned together with the most perfect safety by means of the *compound blow-pipe*, an instrument invented by Prof. Hare, of Philadelphia. Instead of mixing the gases in the same reservoir, they are kept separate until they meet at the point of combustion. An account of this blow-pipe is given by Prof. Silliman, in his edition of Henry's chemistry, together with a list of experiments made with it on various substances. This was the first notice of any experiment made by burning the two gases together, for the purpose of obtaining an intense heat. C.

Emily. You said that rust was an oxyd of iron; how is it, then, that water, or merely dampness, produces it, which, you know, it very frequently does on steel grates, or any iron instruments?

Mrs. B. In that case the metal decomposes the water, or dampness (which is nothing but water in a state of vapour), and obtains the oxygen from it.

Caroline. I thought that it was necessary to bring metals to a very high temperature to enable them to decompose water.

Mrs. B. It is so, if it required that the process should be performed rapidly, and if any considerable quantity is to be decomposed. Rust, you know, is sometimes months in forming, and then it is only the surface of the metal that is oxydated.

Emily. Metals, then, that do not rust, are incapable of spontaneous oxydation, either by air or water?

Mrs. B. Yes; and this is the case with the perfect metals, which, on that account, preserve their metallic lustre so well.

Emily. Are all metals capable of decomposing water, provided their temperature be sufficiently raised?

Mrs. B. No; a certain degree of attraction is requisite, besides the assistance of heat. Water, you recollect, is composed of oxygen and hydrogen; and, unless the affinity of the metal for oxygen be stronger than that of hydrogen, it is in vain that we raise its temperature, for it cannot take the oxygen from the hydrogen. Iron, zinc, tin, and antimony, have a stronger affinity for oxygen than hydrogen has, therefore these four metals are capable of decomposing water. But hydrogen having an advantage over all the other metals with respect to its affinity for oxygen, it not only withholds its oxygen from them, but is even capable, under certain circumstances, of taking the oxygen from the oxyds of these metals.

Emily. I confess that I do not quite understand why hydrogen can take oxygen from those metals that do not decompose water.

Caroline. Now I think I do perfectly. Lead, for instance, will not decompose water, because it has not so strong an attraction for oxygen as hydrogen has. Well, then, suppose the lead to be in a state of oxyd; hydrogen will take the oxygen from the lead, and unite with it to form water, because hydrogen has a stronger attraction for oxygen, than oxygen has for lead; and it is the same with all the other metals which do not decompose water.

Emily. I understand your explanation, Caroline, very well; and I imagine that it is because lead cannot decompose water that it is so much employed for pipes for conveying that fluid.*

Mrs. B. Certainly; lead is, on that account, particularly appropriate to such purposes; whilst, on the contrary, this metal, if it was oxydable by water, would impart to it very noxious qualities, as all oxyds of lead are more or less pernicious.

But, with regard to the oxydation of metals, the most powerful mode of effecting it is by means of acids. These, you know, contain a much greater proportion of oxygen than either air or water; and will, most of them, easily yield it to metals. Thus, you recollect, the zinc plates of the Voltaic battery are oxydated by the acid and water, much more effectually than by water alone.

Caroline. And I have often observed that if I drop vinegar, lemon, or any acid on the blade of a knife, or on a pair of scissors, it will immediately produce a spot of rust.

Emily. Metals have, then, three ways of obtaining oxygen; from the atmosphere, from water, and from acids.

Mrs. B. The two first you have already witnessed, and I shall now show you how metals take the oxygen from an acid. This bottle contains nitric acid; I shall pour some of it over this piece of copper-leaf. . . . . .

Caroline. Oh, what a disagreeable smell!

Emily. And what is it that produces the effervescence and that thick yellow vapour?

Mrs. B. It is the acid, which being abandoned by the greatest part of its oxygen, is converted into a weaker acid, which escapes in the form of gas.

Caroline. And whence proceeds this heat?

Mrs. B. Indeed, Caroline, I think you might now be able to answer that question yourself.

Caroline. Perhaps it is that the oxygen enters into the metal in a more solid state than it existed in the acid, in consequence of which caloric is disengaged.

Mrs. B. If the combination of the oxygen and the metal results from the union of their opposite electricities, of course caloric must be given out.

Emily. The effervescence is over; therefore I suppose that the metal is now oxydated.

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* Lead is capable of decomposing water, and when suffered to stand long in a vessel of this metal, it becomes poisonous. When used merely to convey water, there is but little danger. C.

Mrs. B. Yes. But there is another important connection between metals and acids, with which I must now make you acquainted. Metals, when in the state of oxyds, are capable of being dissolved by acids. In this operation they enter into a chemical combination with the acid, and form an entirely new compound.

Caroline. But what difference is there between the *oxydation* and the *dissolution* of the metal by an acid?

Mrs. B. In the first case, the metal merely combines with a portion of oxygen taken from the acid, which is thus partly deoxygenated, as in the instance you have just seen; in the second case, the metal, after being previously oxydated, is actually dissolved in the acid, and enters into a chemical combination with it, without producing any further decomposition or effervescence.—This complete combination of an oxyd and an acid forms a peculiar and important class of compound salts.

Emily. The difference between an oxyd and a compound salt, therefore, is very obvious; the one consists of a metal and oxygen; the other of an oxyd and an acid.

Mrs. B. Very well: and you will be careful to remember that the metals are incapable of entering into this combination with acids, unless they are previously oxydated; therefore, whenever you bring a metal in contact with an acid, it will be first oxydated and afterwards dissolved, provided that there be a sufficient quantity of acid for both operations.

There are some metals, however, whose solution is more easily accomplished, by diluting the acid in water; and the metal will, in this case, be oxydated, not by the acid, but by the water, which it will decompose. But in proportion as the oxygen of the water oxydates the surface of the metal, the acid combines with it, washes it off, and leaves a fresh surface for the oxygen to act upon: then other coats of oxyd are successively formed, and rapidly dissolved by the acid, which continues combining with the new-formed surfaces of oxyd till the whole of the metal is dissolved. During this process the hydrogen gas of the water is disengaged, and flies off with effervescence.

Emily. Was not this the manner in which the sulphuric acid assisted the iron filings in decomposing water?

Mrs. B. Exactly; and it is thus that several metals, which are incapable alone of decomposing water, are enabled to do it by the assistance of an acid, which, by continually washing off the covering of oxyd, as it is formed, prepares a fresh surface of metal to act upon the water.

Caroline. The acid here seems to act a part not very different from that of a scrubbing-brush.—But pray would not this be a good method of cleaning metallic utensils?

Mrs. B. Yes; on some occasions a weak acid, as vinegar, is used for cleaning copper. Iron plates, too, are freed from the rust on their surface by diluted muriatic acid, previous to their being covered with tin. You must remember, however, that in this mode of cleaning metals the acid should be quickly afterwards wiped off, otherwise it would produce fresh oxyd.

Caroline. Let us watch the dissolution of the copper in the nitric acid; for I am very impatient to see the salt that is to result from it. The mixture is now of a beautiful blue colour; but there is no appearance of the formation of a salt; it seems to be a tedious operation.

Mrs. B. The crystallisation of the salt requires some length of time to be completed; if, however, you are so impatient, I can easily show you a metallic salt already formed.

Caroline. But that would not satisfy my curiosity half so well as one of our own manufacturing.

Mrs. B. It is one of our own preparing that I mean to show you. When we decomposed water a few days since, by the oxydation of iron filings through the assistance of sulphuric acid, in what did the process consist?

Caroline. In proportion as the water yielded its oxygen to the iron, the acid combined with the new-formed oxyd, and the hydrogen escaped alone.

Mrs. B. Very well; the result, therefore, was a compound salt, formed by the combination of sulphuric acid with oxyd of iron. It still remains in the vessel in which the experiment was performed. Fetch it, and we shall examine it.

Emily. What a variety of processes the decomposition of water, by a metal and an acid, implies: 1st, the decomposition of the water; 2dly, the oxydation of the metal; and 3dly, the formation of a compound salt.

Caroline. Here it is, Mrs. B.—What beautiful green crystals! But we do not perceive any crystals in the solution of copper in nitrous acid?

Mrs. B. Because the salt is now suspended in the water which the nitrous acid contains, and will remain so till it is deposited in consequence of rest and cooling.

Emily. I am surprised that a body so opaque as iron can be converted into such transparent crystals.

Mrs. B. It is the union with the acid that produces the transparency; for if the pure metal were melted, and afterwards permitted to cool and crystallise, it would be found just as opaque as before.

Emily. I do not understand the exact meaning of *crystallisation.*

Mrs. B. You recollect that when a solid body is dissolved either by water or caloric it is not decomposed; but that its integrant parts are only suspended in the solvent. When the solution is made in water, the integrant particles of the body will, on the water being evaporated, again unite into a solid mass by the force of their mutual attraction. But when the body is dissolved by caloric alone, nothing more is necessary, in order to make its particles re-unite, than to reduce its temperature. And, in general, if the solvent, whether water or caloric, be slowly separated by evaporation or by cooling, and care taken that the particles be not agitated during their re-union, they will arrange themselves in regular masses, each individual substance assuming a peculiar form or arrangement; and this is what is called crystallisation.

Emily. Crystallisation, therefore, is simply the re-union of the particles of a solid body which has been dissolved in a fluid.*

Mrs. B. That is a very good definition of it. But I must not forget to observe, that *heat* and *water* may unite their solvent powers; and, in this case, crystallisation may be hastened by cooling, as well as by evaporating the liquid.

Caroline. But if the body dissolved is of a volatile nature, will it not evaporate with the fluid?

Mrs. B. A crystallised body held in solution only by water is scarcely ever so volatile as the fluid itself, and care must be taken to manage the heat so that it may be sufficient to evaporate the water only

I should not omit also to mention that bodies, in crystallising from their watery solution, always retain a small portion of water, which remains confined in the crystal in a solid form, and does not re-appear unles the body loses it crystalline state. This is called the *water of crystallisation.* But you must observe, that whilst a body may be separated from its solution in water or caloric simply by cooling or by evaporation, an acid can be taken from a metal with which it is combined only by stronger affinities, which produce a decomposition.

Emily. Are the perfect metals susceptible of being dissolved and converted into compound salts by acids?

Mrs. B. Gold is acted upon by only one acid, the *oxygena-*

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* Not exactly, because the particles of the fluid make a part of the crystal. Crystallisation is that process by which the particles of bodies unite to form solids, of certain, and regular shapes. C.

ted muriatic, a very remarkable acid, which, when in its most concentrated state, dissolves gold or any other metal, by burning them rapidly.

Gold can, it is true, be dissolved likewise by a mixture of two acids, commonly called *aqua regia ;* but this mixed solvent derives that property from containing the peculiar acid which I have just mentioned. Platina is also acted upon by this acid only; silver is dissolved by nitric acid.

Caroline. I think you said that some of the metals might be so strongly oxydated as to become acid?

Mrs. B. There are five metals, arsenic, molybdena, chrome, tungsten, and columbium, which are susceptible of combining with a sufficient quantity of oxygen to be converted into acids.

Caroline. Acids are connected with metals in such a variety of ways, that I am afraid of some confusion in remembering them.—In the first place, acids will yield their oxygen to metals. Secondly, they will combine with them in their state of oxyds, to form compound salts; and lastly, several of the metals are themselves susceptible of acidification.

Mrs. B. Very well; but though metals have so great an affinity for acids, it is not with that class of bodies alone that they will combine. They are most of them in their simple state, capable of uniting with sulphur, with phosphorus, with carbon, and with each other; these combinations, according to the nomenclature which was explained to you on a former occasion, are called *sulphurets*, *phosphorets*, *carburets*, &c.

The metallic phosphorets offer nothing very remarkable. The sulphurets form the peculiar kind of mineral called *pyrites*, from which certain kinds of mineral waters, as those of Harrogate, derive their chief chemical properties. In this combination, the sulphur, together with the iron, have so strong an attraction for oxygen, that they obtain it both from the air and from water, and by condensing it in a solid form, produce the heat which raises the temperature of the water in such a remarkable degree.

Emily. But if pyrites obtain oxygen from water, that water must suffer a decomposition, and hydrogen gas be evolved.

Mrs. B. That is actually the case in the hot sgrings alluded to, which give out an extremely fetid gas, composed of hydrogen impregnated with sulphur.

Caroline. If I recollect right, steel and plumbago, which you mentioned in the last lesson, are both carburets of iron?

Mrs. B. Yes; and they are the only carburets of much consequence.

A curious combination of metals has lately very much attracted the attention of the scientific world: I mean the meteoric stones which fall from the atmosphere. They consist principally of native or pure iron, which is never found in that state in the bowels of the earth* and contain also a small quantity of nickel and chrome, a combination likewise new in the mineral kingdom.

These circumstances have led many scientific persons to believe that those substances have fallen from the moon, or some other planet, while others are of opinion either that they are formed in the atmosphere, or are projected into it by some unknown volcano on the surface of our globe.

Caroline. I have heard much of these stones, but I believe many people are of opinion that they are formed on the surface of the earth, and laugh at their pretended celestial origin.

Mrs. B. The fact of their falling is so well ascertained, that I think no person who has at all investigated the subject, can now entertain any doubt of it. Specimens of these stones have been discovered in all parts of the world, and to each of them some tradition or story of its fall has been found connected. And as the analysis of all those specimens affords precisely the same results, there is strong reason to conjecture that they all proceed from the same source. It is to Mr. Howard that philosophers are indebted for having first analysed these stones, and directed their attention to this interesting subject.

Caroline. But pray, Mrs. B., how can solid masses of nickel be formed from the atmosphere, which consists of the two airs, nitrogen and oxygen?

Mrs. B. I really do not see how they could, and think it much more probable that they fall from the moon, or some other celestial body.—But we must not suffer this digression to take up too much of our time.

The combinations of metals with each other are called alloys;

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* This seems to be a mistake. Several localities of native iron, found in veins are pointed out by authors. In several instances large blocks of native iron have been found on the surface of the earth. One found by Prof. Pallas in Siberia weighed 1600 lbs. Another found in South America is said to weigh 30,000 lbs. &c. These have been suspected to be of meteoric origin, though nothing is known, which makes this certain. Those stones which are known beyond a doubt to have fallen from the atmosphere, have a very different composition. These generally contain the following ingredients, viz. *iron, nickel chrome, oxide of iron, sulphur, silex, lime, magnesia,* and *alumine.* The iron rarely amounts to a quarter of the whole. Accounts are recorded of the falling of stones, sulphur, &c. in every age since the Christian era, and in almost every part of the world. C.

thus brass is an alloy of copper and zinc; bronze, of copper and tin, &c.

Emily. And is not pewter also a combination of metal?

Mrs. B. It is. The pewter made in this country is mostly composed of tin, with a very small proportion of zinc and lead.

Caroline. Block-tin is a kind of pewter, I believe?

Mrs. B. Properly speaking, block-tin means tin in blocks, or square massive ingots; but in the sense in which it is used by ignorant workmen, it is iron plated with tin, which renders it more durable, as tin will not so easily rust. Tin alone, however, would be too soft a metal to be worked for common use, and all tin vessels and utensils are in fact made of plates of iron, thinly coated with tin, which prevents the iron from rusting.

Caroline. Say rather *oxydating*, Mrs. B.—Rust is a word that should be exploded in chemistry.

Mrs. B. Take care, however, not to introduce the word oxydate, instead of rust, in general conversation; for you would probably not be understood, and you might be suspected of affectation.

Metals differ very much in their affinity for each other; some will not unite at all, others readily combine together, and on this property of metals the art of *soldering* depends.

Emily. What is soldering?

Mrs. B. It is joining two pieces of metal together, by a more fusible metal interposed between them. Thus tin is a solder for lead; brass, gold, or silver, are solder for iron, &c.

Caroline. And is not *plating* metals something of the same nature?

Mrs. B. In the operation of plating, two metals are united, one being covered with the other, but without the intervention of a third; iron or copper may thus be covered with gold or silver.

Emily. Mercury appears to me of a very different nature from the other metals.

Mrs. B. One of its greatest peculiarities is, that it retains a fluid state at the temperature of the atmosphere. All metals are fusible at different degrees of heat, and they have likewise each the property of freezing or becoming solid at a certain fixed temperature. Mercury congeals only at seventy-two degrees below the freezing point.

Emily. That is to say, that in order to freeze, it requires a temperature of seventy-two degrees colder than that at which water freezes.

Mrs. B. Exactly so.

Caroline. But is the temperature of the atmosphere ever so low as that?

Mrs. B. Yes, often in Siberia; but happily never in this part of the globe. Here, however, mercury may be congealed by artificial cold; I mean such intense cold as can be produced by some chemical mixtures, or by the rapid evaporation of ether under the air pump.*

Caroline. And can mercury be made to boil and evaporate?

Mrs. B. Yes, like any other liquid; only it requires a much greater degree of heat. At the temperature of six hundred degrees, it begins to boil and evaporate like water.

Mercury combines with gold, silver, tin, and with several other metals; and, if mixed with any of them in a sufficient proportion, it penetrates the solid metal, softens it, loses its own fluidity, and forms an *amalgam*, which is the name given to the combination of any metal with mercury, forming a substance more or less solid, according as the mercury or the other metal predominates.

Emily. In the list of metals there are some whose names I have never before heard mentioned.

Mrs. B. Besides those which Sir H. Davy has obtained, there are several that have been recently discovered, whose properties are yet but little known, as for instance, titanium, which was discovered by the Rev. Mr. Gregor, in the tin-mines of Cornwall; columbium or tantalium, which has lately been discovered by Mr. Hatchett; and osmium, iridium, palladium, and rhodium, all of which Dr. Wollaston and Mr. Tennant found mixed in minute quantities with crude platina, and the distinct existence of which they proved by curious and delicate experiments. More recently still Professor Parhelius has discovered in a pyritic ore, at Fahlun, in Sweden, a metallic substance, which he has called *selenium*, and which has the singular peculiarity of assuming the form of a yellow gas when heated in close vessels. In some of its properties this substance seems to hold a medium between the combustibles and the metals. It bears in particular a strong analogy to sulphur.

Caroline. Arsenic has been mentioned amongst the metals, I had no notion that it belonged to that class of bodies, for I had never seen it but as a powder, and never thought of it but as a most deadly poison.

Mrs. B. In its pure metallic state, I believe, it is not so poisonous; but it has such a great affinity for oxygen, that it absorbs it from the atmosphere at its natural temperature: you have seen it, therefore, only in its state of oxyd, when, from its combination with oxygen, it has acquired its very poisonous properties.

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* By a process analogous to that described, page 72, of this volume.

Caroline. Is it possible that oxygen can impart poisonous qualities? That valuable substance which produces light and fire, and which all bodies in nature are so eager to obtain?

Mrs. B. Most of the metallic oxyds are poisonous, and derive this property from their union with oxygen. The white lead, so much used in paint, owes its pernicious effects to oxygen. In general, oxygen, in a concrete state, appears to be particularly destructive in its effects on flesh or any animal matter; and those oxyds are most caustic that have an acrid burning taste, which proceeds from the metal having but a slight affinity for oxygen, and therefore easily yielding it to the flesh, which it corrodes and destroys.

Emily. What is the meaning of the word *caustic*, which you have just used?

Mrs. B. It expresses that property which some bodies possess, of disorganizing and destroying animal matter, by operating a kind of combustion, or at least a chemical decomposition. You must often have heard of caustic used to burn warts, or other animal excrescences; most of these bodies owe their destructive power to the oxygen with which they are combined. The common caustic, called *lunar caustic*, is a compound formed by the union of nictric acid and silver; and it is supposed to owe its caustic qualities to the oxygen contained in the nitric acid.

Caroline. But, pray, are not acids still more caustic than oxyds, as they contain a greater proportion of oxygen?

Mrs. B. Some of the acids are; but the caustic property of a body depends not only upon the quantity of oxygen which it contains, but also upon its slight affinity for that principle, and the consequent facility with which it yields it.

Emily. Is not this destructive property of oxygen accounted for?

Mrs. B. It proceeds probably from the strong attraction of oxygen for hydrogen; for if the one rapidly absorb the other from the animal fibre, a disorganization of the substance must ensue.

Emily. Caustics are, then, very properly said to *burn* the flesh, since the combination of oxygen and hydrogen is an actual combustion.

Caroline. Now, I think, this effect would be more properly termed an oxydation, as there is no disengagement of light and heat.

Mrs. B. But there really is a sensation of heat produced by the action of caustics.

Emily. If oxygen is so caustic, why does not that which is contained in the atmosphere burn us ?

Mrs. B. Because it is in a gaseous state, and has a greater attraction for its electricity than for the hydrogen of our bodies. Besides, should the air be slightly caustic, we are in a great measure sheltered from its effects by the skin ; you know how much a wound, however trifling, smarts on being exposed to it.

Caroline. It is a curious idea, however, that we should live in a slow fire. But if the air was caustic, would it not have an acrid taste ?

Mrs. B. It possibly may have such a taste, though in so slight a degree, that custom has rendered it insensible.

Caroline. And why is not water caustic ? When I dip my hand into water, though cold, it ought to burn me from the caustic nature of its oxygen.

Mrs. B. Your hand does not decompose the water ; the oxygen in that state is much better supplied with hydrogen than it would be by animal matter, and if its causticity depend on its affinity for that principle, it will be very far from quitting its state of water to act upon your hand. You must not forget that oxyds are caustic in proportion as the oxygen adheres slightly to them.

Emily. Since the oxyd of arsenic is poisonous, its acid, I suppose, is fully as much so ?

Mrs. B. Yes ; it is one of the strongest poisons in nature.

Emily. There is a poison called *verdigris*, which forms on brass and copper, when not kept very clean ; and this, I have heard, is an objection to these metals being made into kitchen utensils. Is this poison likewise occasioned by oxygen ?

Mrs. B. It is produced by the intervention of oxygen ; for verdigris is a compound salt formed by the union of vinegar and copper ; it is of a beautiful green colour, and much used in painting.

Emily. But, I believe, verdigris is often formed on copper when no vinegar has been in contact with it.

Mrs. B. Not real verdigris, but other salts, somewhat resembling it, may be produced by the action of other acids on copper.

The solution of copper in nitric acid, if evaporated, affords a salt which produces an effect on tin that will surprise you, and I have prepared some from the solution we made before, that I might show it to you. I shall first sprinkle some water on this piece of tin-foil, and then some of the salt.—Now observe that I fold it up suddenly, and press it into one lump.

Caroline. What a prodigious vapour issues from it—and sparks of fire I declare!

Mrs. B. I thought it would surprise you. The effect, however, I dare say you could account for, since it is merely the consequence of the oxygen of the salt rapidly entering into a closer combination with the tin.

There is also a beauttful green salt too curious to be omitted; it is produced by the combination of cobalt with muriatic acid, which has the singular property of forming what is called *sympathetic ink.* Characters written with this solution are invisible when cold, but when a gentle heat is applied, they assume a fine bluish green colour.

Caroline. I think one might draw very curious landscapes with the assistance of this ink; I would first make a water-colour drawing of a winter-scene, in which the trees should be leafless, and the grass scarcely green; I would then trace all the verdure with the invisible ink, and whenever I chose to create spring, I should hold it before the fire, and its warmth would cover the landscape with a rich verdure.

Mrs. B. That will be a very amusing experiment, and I advise you by all means to try it.

Before we part, I must introduce to your acquaintance the curious metals which Sir H. Davy has recently discovered. The history of these extraordinary bodies is yet so much in its infancy, that I shall confine myself to a very short account of them; it is more important to point out to you the vast, and apparently inexhaustable, field of research which has been thrown open to our view by Sir H. Davy's memorable discoveries, than to enter into a minute account of particular bodies or experiments.

Caroline. But I have heard that these discoveries, however splendid and extraordinary, are not very likely to prove of any great benefit to the world, as they are rather objects of curiosity than of use.

Mrs. B. Such may be the illiberal conclusions of the ignorant and narrow-minded; but those who can duly estimate the advantages of enlarging the sphere of science, must be convinced that the acquisition of every new fact, however unconnected it may at first appear with practical utility, must ultimately prove beneficial to mankind. But these remarks are scarcely applicable to the present subject; for some of the new metals have already proved eminently useful as chemical agents, and are likely soon to be employed in the arts. For the enumeration of these metals, I must refer you to our list of simple bodies; they are derived from the alkalies, the earths, and three of the acids, all of which had been hitherto considered as undecompoundable or simple bodies.

When Sir H. Davy first turned his attention to the effects of the Voltaic battery, he tried its power on a variety of compound bodies, and gradually brought to light a number of new and interesting facts, which led the way to more important discoveries. It would be highly interesting to trace his steps in this new department of science, but it would lead us too far from our principal object. A general view of his most remarkable discoveries is all that I can aim at, or that you could, at present, understand.

The facility with which compound bodies yielded to the Voltaic electricity, induced him to make trial of its effects on substances hitherto considered as simple, but which he suspected of being compound, and his researches were soon crowned with the most complete success.

The body which he first submitted to the Voltaic battery, and which had never yet been decomposed, was one of the fixed alkalies, called potash. This substance gave out an elastic fluid at the positive wire, which was ascertained to be oxygen, and at the negative wire, small globules of a very high metallic lustre, very similar in appearance to mercury; thus proving that potash, which had hitherto been considered as a simple incombustible body, was in fact a metallic oxyd; and that its incombustibility proceeded from its being already combined with oxygen.

Emily. I suppose the wires used in this experiment were of platina, as they were when you decomposed water; for if of iron, the oxygen would have combined with the wire, instead of appearing in the form of gas.

Mrs. B. Certainly: the metal, however, would equally have been disengaged. Sir H. Davy has distinguished this new substance by the name of POTASSIUM, which is derived from that of the alkali, from which it is procured. I have some small pieces of it in this phial, but you have already seen it, as it is the metal which we burnt in contact with sulphur.

Emily. What is the liquid in which you keep it?

Mrs. B. It is naptha, a bituminous liquid, with which I shall hereafter make you acquainted. It is almost the only fluid in which potassium can be preserved, as it contains no oxygen, and this metal has so powerful an attraction for oxygen, that it will not only absorb it from the air, but likewise from water, or any body whatever that contains it.

Emily. This, then, is one of the bodies that oxydates spontaneously without the application of heat?

Mrs. B. Yes; and it has this remarkable peculiarity, that it attracts oxygen much more rapidly from water than from air; so that when thrown into water, however cold, it actually bursts into flame. I shall now throw a small piece, about the size of a pin's head, on this drop of water.

Caroline. It instantaneously exploded, producing a little flash of light! this is, indeed, a most curious substance!

Mrs. B. By its combustion it is re-converted into potash; and as potash is now decidedly a compound body, I shall not enter into any of its properties till we have completed our review of the simple bodies; but we may here make a few observations on its basis, potassium. If this substance is left in contact with air, it rapidly returns to the state of potash, with a disengagement of heat, but without any flash of light.

Emily. But is it not very singular that it should burn better in water than in air?

Caroline. I do not think so: for if the attraction of potassium for oxygen is so strong that it finds no more difficulty in separating it from the hydrogen in water, than in absorbing it from the air, it will no doubt be more amply and rapidly supplied by water than by air.

Mrs. B. That cannot, however, be precisely the reason, for when potassium is introduced under water, without contact of air, the combustion is not so rapid, and indeed, in that case, there is no luminous appearance; but a violent action takes place, much heat is excited, the potash is regenerated, and hydrogen gas is evolved.

Potassium is so eminently combustible, that instead of requiring, like other metals, an elevation of temperature, it will burn rapidly in contact with water, even below the freezing point. This you may witness by throwing a piece on this lump of ice.

Caroline. It again exploded with flame, and has made a deep hole in the ice.

Mrs. B. This hole contains a solution of potash; for the alkali being extremely soluble, disappears in the water at the instant it is produced. Its presence, however, may be easily ascertained, alkalies having the property of changing paper, stained with turmeric, to a red colour; if you dip one end of this slip of paper into the hole in the ice you will see it change colour, and the same, if you wet it with the drop of water in which the first piece of potassium was burnt.

Caroline. It has indeed changed the paper from yellow to red.

Mrs. B. This metal will burn likewise in carbonic acid gas; a gas that had always been supposed incapable of supporting combustion, as we were unacquainted with any substance that had a greater attraction for oxygen than carbon. Potassium, however, readily decomposes this gas, by absorbing its oxygen, as I shall show you. This retort is filled with carbonic acid gas.—I will put a small piece of potassium in it; but for this combustion a slight elevation of temperature is required, for which purpose I shall hold the retort over the lamp.

Caroline. Now it has taken fire, and burns with violence! It has burst the retort.

Mrs. B. Here is the piece of regenerated potash; can you tell me why it has become so black?

Emily. No doubt it is blackened by the carbon, which, when its oxygen entered into combination with the potassium, was deposited on its surface.

Mrs. B. You are right. This metal is perfectly fluid at the temperature of one hundred degrees; at fifty degrees it is solid, but soft and malleable; at thirty-two degrees it is hard and brittle, and its fracture exhibits an appearance of confused crystallization. It is scarcely more than half as heavy as water; its specific gravity being about six when water is reckoned at ten; so that this metal is actually lighter than any known fluid, even than ether.

Potassium combines with sulphur and phosphorus, forming sulphurets and phosphurets; it likewise forms alloys with several metals, and amalgamates with mercury.

Emily. But can a sufficient quantity of potassium be obtained, by means of the Voltaic battery, to admit of all its properties and relations to other bodies being satisfactorily ascertained?

Mrs. B. Not easily; but I must not neglect to inform you that a method of obtaining this metal in considerable quantities has since been discovered. Two eminent French chemists, Thenard and Gay Lussac, stimulated by the triumph which Sir H. Davy had obtained, attempted to separate potassium from its combination with oxygen, by common chemical means, and without the aid of electricity. They caused red hot potash in a state of fusion to filter through iron turnings in an iron tube, heated to whiteness. Their experiment was crowned with the most complete success; more potassium was obtained by this single operation, than could have been collected in many weeks by the most diligent use of the Voltaic battery.

Emily. In this experiment, I suppose, the oxygen quitted its combination with the potassium to unite with the iron turnings?

Mrs. B. Exactly so; and the potassium was thus obtained in its simple state. From that time it has become a most convenient and powerful instrument of deoxygenation in chemical experiments. This important improvement, engrafted on Sir H. Davy's previous discoveries, served but to add to his glory, since the facts which he had established, when possessed of only a few atoms of this curious substance, and the accuracy of his analytical statements, were all confirmed when an opportunity occurred of repeating his experiments upon this substance, which can now be obtained in unlimited quantities.

Caroline. What a satisfaction Sir H Davy must have felt, when by an effort of genius he succeeded in bringing to light and actually giving existence, to these curious bodies, which without him might perhaps have ever remained concealed from our view!

Mrs. B. The next substance which Sir H. Davy submitted to the influence of the Voltaic battery was *Soda*, the other fixed alkali, which yielded to the same powers of decomposition; from this alkali too, a metallic substance was obtained, very analogous in its properties to that which had been discovered in potash; Sir H. Davy has called it SODIUM. It is rather heavier than potassium, though considerably lighter than water; it is not so easily fusible as potassium.

Encouraged by these extraordinary results, Sir H. Davy next performed a series of beautiful experiments on *Ammonia*, or the volatile alkali, which, from analogy, he was led to suspect might also contain oxygen. This he soon ascertained to be the fact, but he has not yet succeeded in obtaining the basis of ammonia in a separate state; it is from analogy, and from the power which the volatile alkali has, in its gaseous form, to oxydate iron, and also from the amalgams which can be obtained from ammonia by various processes, that the proofs of that alkali being also a metallic oxyd are deduced.

Thus, then, the three alkalies, two of which had always been considered as simple bodies, have now lost all claim to that title, and I have accordingly classed the alkalies amongst the compounds, whose properties we shall treat of in a future conversation.

Emily. What are the other newly discovered metals which you have alluded to in your list of simple bodies?

Mrs. B. They are the metals of the earths which became next the object of Sir H. Davy's researches; these bodies had never yet been decomposed, though they were strongly suspected not only of being compounds, but of being metallic oxyds. From the circumstance of their incombustibility it was conjectured, with some plausibility, that they might possibly be bodies that had been already burnt.

Caroline. And metals, when oxydated, become, to all appearance, a kind of earthy substance.

Mrs. B. They have, besides, several features of resemblance with metallic oxyds; Sir H. Davy had therefore great reason to be sanguine in his expectations of decomposing them, and he was not disappointed. He could not, however, succeed in obtaining the basis of the earths in a pure separate state; but metallic alloys were formed with other metals, which sufficiently proved the existence of the metallic basis of the earths.

The last class of new metallic bodies which Sir H. Davy discovered was obtained from the three undecompounded acids, the boracic, the fluoric, and the muriatic acids; but as you are entirely unacquainted with these bodies, I shall reserve the account of their decomposition till we come to treat of their properties as acids.

Thus in the course of two years, by the unparalleled exertions of a single individual, chemical science has assumed a new aspect. Bodies have been brought to light which the human eye never before beheld, and which might have remained eternally concealed under their impenetrable disguise.

It is impossible at the present period to appreciate to their full extent the consequences which science or the arts may derive from these discoveries; we may, however, anticipate the most important results.

In chemical analysis we are now in possession of more energetic agents of decomposition than were ever before known.

In geology new views are opened, which will probably operate a revolution in that obscure and difficult science. It is already proved that all the earths, and, in fact, the solid surface of this globe, are metallic bodies mineralized by oxygen, and as our planet has been calculated to be considerably more dense upon the whole than it is on the surface, it is reasonable to suppose that the interior of the earth is composed of a metallic mass, the surface of which only has been mineralized by the atmosphere.

The eruptions of volcanos, those stupendous problems of nature, admit now of an easy explanation.* For if the bowels of the earth are the grand recess of these newly discovered inflammable bodies, whenever water penetrates into them, combustions and explosions must take place; and it is remarkable that the lava which is thrown out, is the very kind of substance which might be expected to result from these combustions.

I must now take my leave of you; we have had a very long conversation to-day, and I hope you will be able to recollect what you have learnt. At our next interview we shall enter on a new subject.

CONVERSATION XIII.

ON THE ATTRACTION OF COMPOSITION.

Mrs. B. HAVING completed our examination of the simple or elementary bodies, we are now to proceed to those of a compound nature; but before we enter on this extensive subject, it will be necessary to make you acquainted with the principal laws by which chemical combinations are governed.

You recollect, I hope, what we formerly said of the nature of the attraction of composition, or chemical attraction, or affinity, as it is also called?

Emily. Yes, I think, perfectly; it is the attraction that subsists between bodies of a different nature, which occasions them to combine and form a compound, when they come in contact, and, according to Sir H. Davy's opinion, this effect is produced by the attraction of the opposite electricities, which prevail in bodies of different kinds.

Mrs. B. Very well; your definition comprehends the first law of chemical attraction, which is, that *it takes place only between bodies of a different nature;* as, for instance, between an acid and an alkali; between oxygen and a metal, &c.

Caroline. That we understand of course; for the attraction between particles of a similar nature is that of aggregation, or cohesion, which is independent of any chemical power.

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* It is always easy to form a theory. But an explanation of these "stupendous problems of nature," we believe has not yet been demonstrated to the satisfaction of all, though great learning and immense labor has been bestowed on the subject. If the "easy explanation" is founded on the data here proposed, viz. that the solid surface of our globe consists of nothing except metals and oxygen—such a theory in the present state of knowledge, must chiefly consist of *supposition* piled on *supposition:* there being as yet no proof that the crust of the earth is formed only of these two elements. C.

Mrs. B. The 2d law of chemical attraction is, that *it takes place only between the most minute particles of bodies;* therefore, the more you divide the particles of the bodies to be combined, the more readily they act upon each other.

Caroline. That is again a circumstance which we might have supposed, for the finer the particles of the two substances are, the more easily and perfectly they will come in contact with each other, which must greatly facilitate their union. It was for this purpose, you said, that you used iron filings, in preference to wires or pieces of iron, for the decomposition of water.

Mrs. B. It was once supposed that no mechanical power could divide bodies into particles sufficiently minute for them to act on each other; and that, in order to produce the extreme division requisite for a chemical action, one, if not both of the bodies, should be in a fluid state. There are, however, a few instances in which two solid bodies, very finely pulverized, exert a chemical action on one another;* but such exceptions to the general rule are very rare indeed.

Emily. In all the combinations that we have hitherto seen, one of the constituents has, I believe, been either liquid or aëriform. In combustions, for instance, the oxygen is taken from the atmosphere, in which it existed in the state of gas; and whenever we have seen acids combine with metals or with alkalies, they were either in a liquid or an aëriform state.

Mrs. B. The 3d law of chemical attraction is, that *it can take place between two, three, four, or even a greater number of bodies.*

Caroline. Oxyds and acids are bodies composed of two constituents; but I recollect no instance of the combination of a greater number of principles.

Mrs. B. The compound salts, formed by the union of the metals with acids, are composed of three principles. And there are salts formed by the combination of the alkalies with the earths which are of a similar description.

Caroline. Are they of the same kind as the metallic salts?

Mrs. B. Yes; they are very analogous in their nature, although different in many of their properties.

A methodical nomenclature, similar to that of the acids, has been adopted for the compound salts. Each individual salt derives its name from its constituent parts, so thate very name implies a knowledge of the composition of the salt.

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* This is the case with muriate of ammonia and quicklime. C.

The three alkalies, the alkaline earths, and the metals, are called *salifiable bases* or *radicals;* and the acids, *salifying principles.* The name of each salt is composed both of that of the acid and the salifiable base; and it terminates in *at* or *it*, according to the degree of the oxygenation of the acid. Thus, for instance, all those salts which are formed by the combination of the sulphuric acid with any of the salifiable bases are called *sulphats*, and the name of the radical is added for the specific distinction of the salt; if it be potash, it will compose a *sulphat of potash;* if ammonia, *sulphat of ammonia*, &c.

Emily. The crystals which we obtained from the combination of iron and sulphuric acid were therefore *sulphat of iron?*

Mrs. B. Precisely; and those which we prepared by dissolving copper in nitric acid, *nitrat of copper*, and so on.—But this is not all: if the salt be formed by that class of acids which ends in *ous*, (which you know indicates a less degree of oxygenation,) the termination of the name of the salt will be in *it*, as *sulphit of potash, sulphit of ammonia*, &c.

Emily. There must be an immense number of compound salts, since there is so great a variety of salifiable radicals, as well as of salifying principles.

Mrs. B. Their real number cannot be ascertained, since it increases every day. But we must not proceed further in the investigation of the compound salts, until we have completed the examination of the nature of the ingredients of which they are composed.

The 4th law of chemical attraction is, that *a change of temperature always takes place at the moment of combination.* This arises from the extrication of the two electricities in the form of caloric, which always occurs when bodies unite; and also sometimes in part from a change of capacity of the bodies for heat, which always takes place when the combination is attended with an increase of density, but more especially when the compound passes from the liquid to the solid form. I shall now show you a striking instance of a change of temperature from chemical union, merely by pouring some nitrous acid on this small quantity of oil of turpentine—the oil will instantly combine with the oxygen of the acid, and produce a considerable change of temperature.

Caroline. What a blaze! The temperature of the oil and the acid must be greatly raised, indeed, to produce such a violent combustion.

Mrs. B. There is, however, a peculiarity in this combustion, which is, that the oxygen, instead of being derived from the atmosphere alone, is principally supplied by the acid itself.

Emily. And are not all combustions instances of the change of temperature produced by the chemical combination of two bodies?

Mrs. B. Undoubtedly; when oxygen loses its gaseous form, in order to combine with a solid body, it becomes condensed, and the caloric evolved produces the elevation of temperature. The specific gravity of bodies is at the same time altered by chemical combination; for in consequence of a change of capacity for heat, a change of density must be produced.

Caroline. That was the case with the sulphuric acid and water, which, by being mixed together, gave out a great deal of heat, and increased in density.

Mrs. B. The 5th law of chemical attraction is, that *the properties which characterise bodies, when separate, are altered or destroyed by their combination.*

Caroline. Certainly; what, for instance, can be so different from water as the hydrogen and oxygen gases?

Emily. Or what more unlike sulphat of iron than iron or sulphuric acid?

Mrs. B. Every chemical combination is an illustration of this rule. But let us proceed—

The 6th law is, that *the force of chemical affinity between the constituents of a body is estimated by that which is required for their separation.* This force is not always proportional to the facility with which bodies unite; for manganese, for instance, which, you know, is so much disposed to unite with oxygen that it is never found in a metallic state, yields it more easily than any other metal.

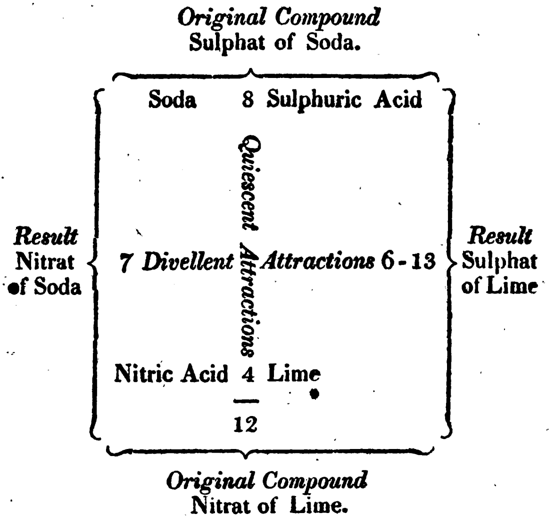
Emily. But, Mrs. B., you speak of estimating the force of attraction between bodies, by the force required to separate them; how can you measure these forces?

Mrs. B. They cannot be precisely *measured,* but they are comparatively ascertained by experiment, and can be represented by numbers which express the relative degrees of attraction.

The 7th law is, that *bodies have amongst themselves different degrees of attraction.* Upon this law, (which you may have discovered yourselves long since,) the whole science of chemistry depends; for it is by means of the various degrees of affinity which bodies have for each other, that all the chemical compositions and decompositions are effected. Every chemical fact or experiment is an instance of the same kind; and whenever the decomposition of a body is performed by the addition of any single new substance, it is said to be effected by *simple elective attractions.* But it often happens that no simple substance will decompose a body, and that, in order to effect this, you must offer to the compound a body which is itself composed of two, or sometimes three principles, which would not, each separately, perform the decomposition. In this case there are two new compounds formed in consequence of a reciprocal decomposition and recomposition. All instances of this kind are called *double elective attractions.*

Caroline. I confess I do not understand this clearly.

Mrs. B. You will easily comprehend it by the assistance of this diagram, in which the reciprocal forces of attraction are represented by numbers:



We here suppose that we are to decompose sulphat of soda; that is, to separate the acid from the alkali; if, for this purpose we add some lime, in order to make it combine with the acid, we shall fail in our attempt, because the soda and the sulphuric acid attract each other by a force which is superior, and (by way of supposition) is represented by the number 8; while the lime tends to unite with this acid by an affinity equal only to the number 6. It is plain, therefore, that the sulphat of soda will not be decomposed, since a force equal to 8 cannot be overcome by a force equal only to 6.

Caroline. So far, this appears very clear.

Mrs. B. If, on the other hand, we endeavour to decompose this salt by nitric acid, which tends to combine with soda, we shall be equally unsuccessful, as nitric acid tends to unite with the alkali by a force equal only to 7.

In neither of these cases of simple elective attraction, therefore, can we accomplish our purpose. But let us previously combine together the lime and nitric acid, so as to form a nitrat of lime, a compound salt, the constituents of which are united by a power equal to 4. If then we present this compound to the sulphat of soda, a decomposition will ensue, because the sum of the forces which tend to preserve the two salts in their actual state is not equal to that of the forces which tend to decompose them, and to form new combinations. The nitric acid, therefore, will combine with the soda, and the sulphuric acid with the lime.*

Caroline. I understand you now very well. This double effect takes place because the numbers 8 and 4, which represent the degrees of attraction of the constituents of the two original salts, make a sum less than the numbers 7 and 6, which represent the degrees of attraction of the two new compounds that will in consequence be formed.

Mrs. B. Precisely so.

Caroline. But what is the meaning of *quiescent* and *divellent* forces, which are written in the diagram?

Mrs. B. Quiescent forces are those which tend to preserve compounds in a state of rest, or such as they actually are: divellent forces, those which tend to destroy that state of combination, and to form new compounds.

These are the principal circumstances relative to the doctrine of chemical attractions, which have been laid down as rules by modern chemists; a few others might be mentioned respecting the same theory, but of less importance, and such as would take us too far from our plan. I should, however, not omit to mention that Mr. Berthollet, a celebrated Fremch chemist, has questioned the uniform operation of elective attraction, and has advanced the opinion, that, in chemical combinations, the changes which take place depend not only upon the affinities, but also, in some degree, on the respective quantities of the substances concerned, on the heat applied during the process, and some other circumstances.

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* Suppose we say thus. The sulphuric acid attracts *soda* with a stronger force than it does *lime*, and *soda* has a stronger affinity for *sulphuric acid* than it has for *nitric acid*. It is plain then, that neither lime nor nitric acid alone will decompose the sulphat of soda. Now if we unite the nitric acid and lime, we form *nitrate* of *lime*. But the nitric acid has not so strong an affinity for the lime as it has for soda. On mixing the two salts in solution, therefore, the nitric acid quits the lime, and combines with the soda. This leaves the sulphuric acid and the lime free and uncombined; they then unite and form sulphat of lime. C.

Caroline. In that case, I suppose, there would hardly be two compounds exactly similar, though composed of the same materials?

Mrs. B. On the contrary, it is found that a remarkable uniformity prevails, as to proportions, between the ingredients of bodies of similar composition. Thus water, as you may recollect to have seen in a former conversation, is composed of two volumes of hydrogen gas to one of oxygen, and this is always found to be precisely the proportion of its conitituents, from whatever source the water be derived. The same uniformity prevails with regard to the various salts; the acid and alkali, in each kind of salt, being always found to combine in the same proportion. Sometimes, it is true, the same acid, and the same alkali are capable of making two distinct kinds of salts; but in all these cases it is found that one of the salts contains just twice, or in some instances, thrice as much acid, or alkali, as the other.*

Emily. If the proportions in which bodies combine are so constant and so well defined, how can Mr. Berthollet's remark be reconciled with this uniform system of combination?

Mrs. B. Great as that philosopher's authority is in chemistry, it is now generally supposed that his doubts on this subject were in a great degree groundless, and that the exceptions he has observed in the laws of definite proportions, have been only apparent, and may be accounted for consistently with those laws.

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* The student already understands, that in chemical combinations the union takes place only between the particles or atoms, of substances. These atoms, it is supposed are indivisible, being the ultimate particles of which bodies are composed. In chemical combinations, then, where substances are capable of uniting in only one proportion, this must be atom to atom. Thus oxygen and hydrogen unite only in the proportions of 100 of the former to 750 of the latter by weight. Here an atom of oxygen unites to an atom of hydrogen to form water; but the atoms of oxygen are seven and an half times heavier than those of hydrogen.

When substances unite in several proportions. the second and third are always multiples of the first. Thus 100 parts of manganese, will unite to 14, 28, 42, or 56 of oxygen, but not with any intermediate quantity, as with 12, 20, 60, &c. This law of definite proportions, so far as is known, holds good, where the resulting compound differs widely from either of the substances of which it is composed, as in the salts, compound minerals, &c. The theory of definite proportions is explained by supposing that a substance which we shall call A, unites with another substance B, atom to atom, and that this forms a certain compound. When they unite in the second proportion, two atoms of B unite to one of A, and this forms another compound, and so on, until the atoms of A can unite to no more of B. C.

Caroline. Pray, Mrs. B., can you decompose a salt by means of electricity, in the same way as we decompose water?

Mrs. B. Undoubtedly; and I am glad this question occurred to you, because it gives me an opportunity of showing you some very interesting experiments on the subject.

If we dissolve a quantity, however small, of any salt in a glass of water, and if we plunge into it the extremities of the wires which proceed from the two ends of the Voltaic battery, the salt will be gradually decomposed, the acid being attracted by the positive, and the alkali by the negative wire.

Emily. But how can you render that decomposition perceptible?

Mrs. B. By placing in contact with the extremities of each wire, in the solution, pieces of paper stained with certain vegetable colours, which are altered by the contact of an acid or an alkali. Thus this blue vegetable preparation called litmus becomes red when touched by an acid; and the juice of violets becomes green by the contact of an alkali.

But the experiment can be made in a much more distinct manner, by receiving the extremities of the wires into two different vessels, so that the alkali shall appear in one vessel and the acid in the other.

Caroline. But then the Voltaic circle will not be completed; how can any effect be produced?

Mrs. B. You are right; I ought to have added that the two vessels must be connected together by some interposed substance capable of conducting electricity. A piece of moistened cotton-wick answers this purpose very well. You see that the cotton (PLATE XIII. fig. 2. c.) has one end immersed in one glass and the other end in the other, so as to establish a communication between any fluids contained in them. We shall now put into each of the glasses a little glauber salt, or sulphat of soda, (which consists of an acid and an alkali,) and then we shall fill the glasses with water, which will dissolve the salt. Let us now connect the glasses by means of the wires (e, d,) with the two ends of the battery, thus ....

Caroline. The wires are already giving out small bubbles; is this owing to the decomposition of salt?

Mrs. B. No; these are bubbles produced by the decomposition of the water, as you saw in a former experiment. In order to render the separation of the acid from the alkali visible, I pour into the glass (a,) which is connected with the positive

Fig. 1.

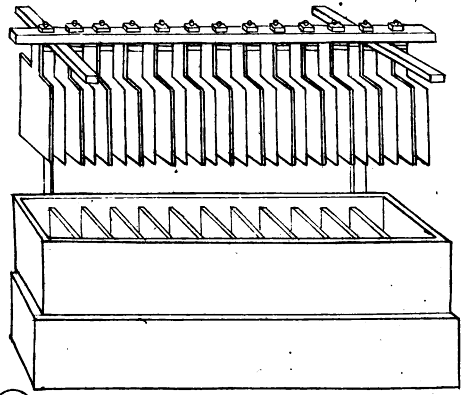

Fig. 2.

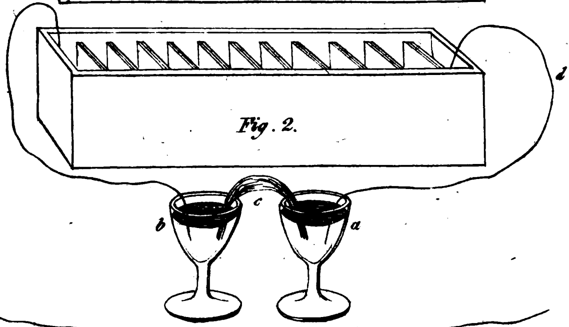

Fig. 3.

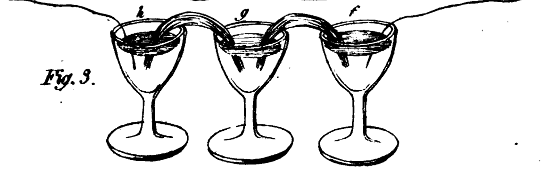

Fig. 4.

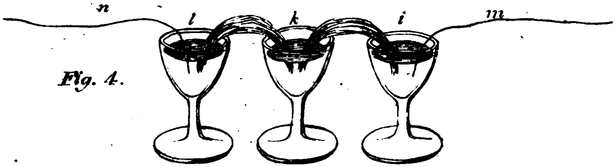

Fig. 1. Voltaic Battery of improved construction with the Plates out of the Cels
Fig. 1. 2. 3 & 4 Instances of Chemical decomposition by the Voltaic Battery.

wire, a few drops of a solution of litmus, which the least quantity of acid turns red; and in the other glass (b,) which is connected with the negative wire, I pour a few drops of the juice of violets . . . .

Emily. The blue solution is already turning red all round the wire.

Caroline. And the violet solution is beginning to turn green. This is indeed very singular!

Mrs. B. You will be still more astonished when we vary the experiment in this manner:—These three glasses (fig. 3. f, g, h,) are, as in the former instance, connected together by wetted cotton, but the middle one alone contains a saline solution, the two others containing only distilled water, coloured as before by vegetable infusions. Yet, on making the connection with the battery, the alkali will appear in the negative glass (h,) and the acid in the positive glass (f,) though neither of them contained anly saline matter.

Emily. So that the acid and the alkali must be conveyed right and left from the central glass, into the other glasses, by means of the connecting moistened cotton?

Mrs. B. Exactly so; and you may render the experiment still more striking, by putting into the central glass (k, fig. 4.) an alkaline solution, the glauber salt being placed into the negative glass (l,) and the positive glass (i) containing only water. The acid will be attracted by the positive wire (m,) and will actually appear in the vessel (i,) after passing through the alkaline solution (k,) without combining with it, although, you know, acids and alkalies are so much disposed to combine.—But this conversation has already much exceeded our usual limits, and we cannot enlarge more upon this interesting subject at present.

◆

CONVERSATION XIV.

ON ALKALIES.

Mrs. B. HAVING now given you some idea of the laws by which chemical attractions are governed, we may proceed to the examination of bodies which are formed in consequence of these attractions.

The first class of compounds that present themselves to our notice, in our gradual ascent to the most complicated combinations, are bodies composed of only two principles. The sulphurets, phosphurets, carburets, &c. are of this description; but the most numerous and important of these compounds are the combination of oxygen with the various simple substances with which it has a tendency to unite. Of these you have already acquired some knowledge, but it will be necessary to enter into further particulars respecting the nature and properties of those most deserving our notice. Of this class are the ALKALIES and the EARTHS, which we shall successively examine.

We shall first take a view of the alkalies, of which there are three, viz. POTASH, SODA, and AMMONIA. The two first are called *fixed alkalies*,* because they exist in a solid form at the temperature of the atmosphere, and require a great heat to be volatilised. They consist, as you already know, of metallic bases combined with oxygen. In potash, the proportions are about eighty-six parts of potassium to fourteen of oxygen; and in soda, seventy-seven parts of sodium to twenty-three of oxygen. The third alkali, ammonia, has been distinguished by the name of *volatile alkali*, because its natural form is that of gas. Its composition is of a more complicated nature, of which we shall speak hereafter.

Some of the earths bear so strong a resemblance in their properties to the alkalies, that it is difficult to know under which head to place them. The celebrated French chemist, Fourcroy, had classed two of them (barytes and strontites) with the alkalies; but as lime and magnesia have almost an equal title to that rank, I think it better not to separate them, and therefore have adopted the common method of classing them with the earths, and of distinguishing them by the name of *alkaline earths*.

The general properties of alkalies are, an acrid burning taste, a pungent smell, and a caustic action on the skin and flesh;

Caroline. I wonder that they should be caustic, Mrs. B., since they contain so little oxygen.

Mrs. B. Whatever substance has an affinity for any one of the constituents of animal matter, sufficiently powerful to decompose it, is entitled to the appellation of caustic. The alkalies, in their pure state, have a very strong attraction for water, for hydrogen, and for carbon, which, you know, are the constituent principles of oil, and it is chiefly by absorbing these substances from animal matter that they effect its decomposition; for, when diluted with a sufficient quantity of water, or combined with any oily substance, they lose their causticity.

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* It has already been stated that a third fixed alkali has lately been discovered by Mr. Arforedson, which has been called *lithion*. It was first found in a Swedish mineral called *petalite;* but has since been detected in some other minerals. Though this alkali resembles potash and soda in its general properties, yet it is decidedly an alkaline substance of its own, capable of forming different salts with the acids, and having in particular the property of combining with much greater proportions of acid than the other alkalies.

But, to return to the general properties of alkalies—they change, as we have already seen, the colour of syrup of violets, and other blue vegetable infusions, to green; and have, in general, a very great tendency to unite with acids, although the respective qualities of these two classes of bodies form a remarkable contrast.

We shall examine the result of the combination of acids and alkalies more particularly hereafter. It will be sufficient at present to inform you, that whenever acids are brought in contact with alkalies, or alkaline earths, they unite with a remarkable eagerness, and form compounds perfectly different from either of their constituents; these bodies are called *neutral* or *compound salts*.

The dry white powder which you see in this phial is pure caustic POTASH; it is very difficult to preserve it in this state, as it attracts, with extreme avidity, the moisture from the atmosphere, and if the air were not perfectly excluded, it would, in a very short time, be actually melted.

Emily. It is then, I suppose, always found in a liquid state?

Mrs. B. No; it exists in nature in a great variety of forms and combinations, but is never found in its pure separate state; it is combined with carbonic acid, with which it exists in every part of the vegetable kingdom, and is most commonly obtained from the ashes of vegetables, which are the residue that remains after all the other parts have been volatilised by combustion.

Caroline. But you once said, that after all the volatile parts of a vegetable were evaporated, the substance that remained was charcoal?

Mrs. B. I am surprised that you should still confound the processes of volatilisation and combustion. In order to procure charcoal, we evaporate such parts as can be reduced to vapour by the operation of heat alone; but when we *burn* the vegetable, we burn the carbon also, and convert it into carbonic acid gas.

Caroline. That is true; I hope I shall make no more mistakes in my favonrite theory of combustion.

Mrs. B. Potash derives its name from the *pots* in which the vegetables, from which it was obtained, used formerly to be burnt; the alkali remained mixed with the ashes at the bottom, and was thence called potash.

Emily. The ashes of a wood-fire, then, are potash, since they are vegetable ashes?

Mrs. B. They always contain more or less potash, but are very far from consisting of that substance alone, as they are a mixture of various earths and salts which remain after the combustion of vegetables, and from which it is not easy to separate the alkali in its pure form. The process by which potash is obtained, even in the imperfect state in which it is used in the arts, is much more complicated than simple combustion. It was once deemed impossible to separate it entirely from all foreign substances, and it is only in chemical laboratories that it is to be met with in the state of purity in which you find it in this phial. Wood-ashes are, however, valuable for the alkali which they contain, and are used for some purposes without any further preparation. Purified in a certain degree, they make what is commonly called *pearl-ash*, which is of great efficacy in taking out grease, in washing linen, &c.; for potash combines readily with oil or fat, with which it forms a compound well known to you under the name of *soap*.

Caroline. Really! Then I should think it would be better to wash all linen with pearl-ash than with soap, as, in the latter case, the alkali being already combined with oil, must be less efficacious in extracting grease.

Mrs. B. Its effect would be too powerful on fine linen, and would injure its texture; pearl-ash is therefore only used for that which is of a strong coarse kind. For the same reason you cannot wash your hands with plain potash; but, when mixed with oil in the form of soap, it is soft as well as cleansing, and is therefore much better adapted to the purpose.

Caustic potash, as we already observed, acts on the skin, and animal fibre, in virtue of its attraction for water and oil, and converts all animal matter into a kind of saponaceous jelly.

Emily. Are vegetables the only source from which potash can be derived?

Mrs. B. No: for though far most abundant in vegetables, it is by no means confined to that class of bodies, being found also on the surface of the earth, mixed with various minerals, especially with earths and stones, whence it is supposed to be conveyed into vegetables by the roots of the plant. It is also met with, though in very small quantities, in some animal substances. The most common state of potash is that of *carbonat;* I suppose you understand what that is?

Emily. I believe so; though I do not recollect that you ever mentioned the word before. If I am not mistaken, it must be a compound salt, formed by the union of carbonic acid with potash.

Mrs. B. Very true; you see how admirably the nomenclature of modern chemistry is adapted to assist the memory; when you hear the name of a compound, you necessarily learn what are its constituent parts; and when you are acquainted with these constituents, you can immediately name the compound which they form.

Caroline. Pray, how were bodies arranged and distinguished before this nomenclature was introduced?

Mrs. B. Chemistry was then a much more difficult study; for every substance had an arbitrary name, which it derived either from the person who discovered it, as *Glauber's salts* for instance; or from some other circumstance relative to it, though quite unconnected with its real nature, as *potash.*

These names have been retained for some of the simple bodies; for as this class is not numerous, and therefore can easily be remembered, it has not been thought necessary to change them.

Emily. Yet I think it would have rendered the new nomenclature more complete to have methodised the names of the elementary, as well as of the compound bodies, though it could not have been done in the same manner. But the names of the simple substances might have indicated their nature, or, at least, some of their principal properties; and if, like the acids and compound salts, all the simple bodies had a similar termination, they would have been immediately known as such. So complete and regular a nomenclature would, I think, have given a clearer and more comprehensive view of chemistry than the present, which is a medley of the old and new terms.

Mrs. B. But you are not aware of the difficulty of introducing into science an entire set of new terms; it obliges all the teachers and professors to go to school again, and if some of the old names, that are least exceptionable, were not left as an introduction to the new ones, few people would have had industry and perseverance enough to submit to the study of a completely new language; and the inferior classes of artists, who can only act from habit and routine, would, at least for a time, have felt material inconvenience from a total change of their habitual terms. From these considerations, Lavoisier and his colleagues, who invented the new nomenclature, thought it most prudent to leave a few links of the old chain, in order to connect it with the new one. Besides, you may easily conceive the inconvenience which might arise from giving a regular nomenclature to substances, the simple nature of which is always uncertain; for the new names might, perhaps, have proved to have been founded in error. And, indeed, cautious as the inventors of the modern chemical language have been, it has already been found necessary to modify it in many respects. In those few cases, however, in which new terms have been adopted to designate simple bodies, these names have been so contrived as to indicate one of the chief properties of the body in question; this is the case with oxygen, which, as I explained to you, signifies generator of acids; and hydrogen generator of water. If all the elementary bodies had a similar termination, as you propose, it would be necessary to change the name of any that might hereafter be found of a compound nature, which would be very inconvenient in this age of discovery.

But to return to the alkalies.—We shall now try to melt some of this caustic potash in a little water, as a circumstance occurs during its solution very worthy of observation.—Do you feel the heat that is produced?

Caroline. Yes, I do; but is not this directly contrary to our theory of latent heat, according to which heat is disengaged when fluids become solid, and cold produced when solids are melted.

Mrs. B. The latter is really the case in all solutions; and if the solution of caustic alkalies seems to make an exception to the rule, it does not, I believe, form any solid objection to the theory. The matter may be explained thus: When water first comes in contact with the potash, it produces an effect similar to the slaking of lime, that is, the water is solidified in combining with the potash, and thus loses its latent heat; this is the heat that you now feel, and which is, therefore, produced not by the melting of the solid, but by the solidification of the fluid. But when there is more water than the potash can absorb and solidify, the latter then yields to the solvent power of the water; and if we do not perceive the cold produced by its melting, it is because it is counterbalanced by the heat previously disengaged.*

A very remarkable property of potash is the formation of glass by its fusion with siliceous earth. You are not yet acquainted with this last substance, further than its being in the list of simple bodies. It is sufficient for the present, that you should know that sand and flint are chiefly composed of it; alone, it is infusible, but mixed with potash, it melts when exposed to the heat of a furnace, combines with the alkali, and runs into glass.

Caroline. Who would ever have supposed that the same substance which converts transparent oil into such an opaque body as soap, should transform that opaque substance, sand, into transparent glass!

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* This defence of the general theory, however plausible, is liable to some obvious objections. The phenomenon might perhaps be better accounted for by supposing that a solution of alkali in water has less capacity for heat than either water or alkali in their separate state.

Mrs. B. The transparency, or opacity of bodies, does not, I conceive, depend so much upon their intimate nature, as upon the arrangement of their particles: we cannot have a more striking instance of this, than is afforded by the different states of carbon, which, though it commonly appears in the form of a black opaque body, sometimes assumes the most dazzling transparent form in nature, that of diamond, which, you recollect, is carbon, and which, in all probability, derives its beautiful transparency from the peculiar arrangement of its particles during their crystallisation.

Emily. I never should have supposed that the formation of glass was so simple a process as you describe it.

Mrs. B. It is by no means an easy operation to make perfect glass; for if the sand or flint, from which the siliceous earth is obtained, be mixed with any metallic particles, or other substance, which cannot be vitrified, the glass will be discoloured, or defaced, by opaque specks.

Caroline. That, I suppose, is the reason why objects so often appear irregular and distorted through a common glass-window.

Mrs. B. This species of imperfection proceeds, I believe, from another cause. It is extremely difficult to prevent the lower part of the vessels, in which the materials of glass are fused, from containing a more dense vitreous matter than the upper, on account of the heavier ingredients falling to the bottom. When this happens, it occasions the appearance of veins or waves in the glass, from the difference of density in its several parts, which produces an irregular refraction of the rays of light which pass through it.

Another species of imperfection sometimes arises from the fusion not being continued for a length of time sufficient to combine the two ingredients completely, or from the due proportion of potash and silex (which are as two to one) not being carefully observed; the glass, in those cases, will be liable to alteration from the action of the air, of salts, and especially of acids, which will effect its decomposition by combining with the potash, and forming compound salts.

Emily. What an extremely useful substance potash is!

Mrs. B. Besides the great importance of potash in the manufactures of glass and soap, it is of very considerable utility in many of the other arts, and in its combinations with several acids, particularly the nitric, with which it forms saltpetre.

Caroline. Then saltpetre must be a *nitrat of potash*? But we are not yet acquainted with the nitric acid?

Mrs. B. We shall therefore defer entering into the particulars of these combinations till we come to a general review of the compound salts. In order to avoid confusion, it will be better at present to confine ourselves to the alkalies.

Emily. Cannot you show us the change of colour which you said the alkalies produced on blue vegetable infusions?

Mrs. B. Yes, very easily. I shall dip a piece of white paper into this syrup of violets, which, you see, is of a deep blue, and dyes the paper of the same colour.—As soon as it is dry, we shall dip it into a solution of potash, which, though itself colourless, will turn the paper green—*

Caroline. So it has, indeed! And do the other alkalies produce a similar effect?

Mrs. B. Exactly the same.—We may now proceed to SODA, which, however important, will detain us but a very short time; as in all its general properties it very strongly resembles potash; indeed, so great is their similitude, that they have been long confounded, and they can now scarcely be distinguished, except by the difference of the salts which they form with acids.

The great source of this alkali is the sea, where, combined with a peculiar acid, it forms the salt with which the waters of the ocean are so strongly impregnated.

Emily. Is not that the common table salt?

Mrs. B. The very same; but again we must postpone entering into the particulars of this interesting combination, till we treat of the neutral salts. Soda may be obtained from common salt; but the easiest and most usual method of procuring it is by the combustion of marine plants, an operation perfectly analogous to that by which potash is obtained from vegetables.

Emily. From what does soda derive its name?

Mrs. B. From a plant called by us *soda*, and by the Arabs *kali*, which affords it in great abundance. Kali has, indeed, given its name to the alkalies in general.

Caroline. Does soda form glass and soap in the same manner as potash?

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* A very pretty experiment on the change of colours may be made as follows: Make a tincture, by pouring boiling water on red cabbage and let it stand a while. Put it into a vial. The colour will be purple. Take two wine glasses, and into one put a few drops of sulphuric acid, and into the other the same quantity of a strong solution of potash. So little of either will do, that the glasses may be inverted for a moment. Then pour the tincture into each, and the one containing the acid will appear a most beautiful red, and the other as beautiful a green. C.

Mrs. B. Yes, it does; it is of equal importance in the arts, and is even preferred to potash for some purposes; but you will not be able to distinguish their properties till we examine the compound salts which they form with acids; we must therefore leave soda for the present, and proceed to AMMONIA or the VOLATILE ALKALI.

Emily. I long to hear something of this alkali; is it not of the same nature as hartshorn?

Mrs. B. Yes it is, as you will see by-and-bye. This alkali is seldom found in nature in its pure state; it is most commonly extracted from a compound salt, called *sal ammoniac*, which was formerly imported from *Ammonia*, a region of Libya, from which both these salts and the alkali derive their names. The crystals contained in this bottle are specimens of this salt, which consist of a combination of ammonia and muriatic acid.

Caroline. Then it should be called *muriatic of ammonia;* for though I am ignorant what muriatic acid is, yet I know that its combination with ammonia cannot but be so called; and I am surprised to see sal ammoniac inscribed on the label.

Mrs. B. That is the name by which it has been so long known, that the modern chemists have not yet succeeded in banishing it altogether; and it is still sold under that name by druggists, though by scientific chemists it is more properly called muriat of ammonia.

Caroline. Both the popular and the common name should be inscribed on labels—this would soon introduce the new nomenclature.

Emily. By what means can the ammonia be separated from the muriatic acid?

Mrs. B. By chemical attraction; but this operation is too complicated for you to understand, till you are better acquainted with the agency of affinities.

Emily. And when extracted from the salt, what kind of substance is ammonia?

Mrs. B. Its natural form, at the temperature of the atmosphere, when free from combination, is that of gas; and in this state it is called *ammoniacal gas*. But it mixes very readily with water, and can be thus obtained in a liquid form.

Caroline. You said that ammonia was more complicated in its composition than the other alkalies; pray of what principles does it consist?

Mrs. B. It was discovered a few years since, by Berthollet, a celebrated French chemist, that it consisted of about one part of hydrogen to four parts of nitrogen. Having heated ammoniacal gas under a receiver, by causing the electrical spark to pass repeatedly through it, he found that it increased considerably in bulk, lost all its alkaline properties, and was actually converted into hydrogen and nitrogen gases; and from the latest and most accurate experiments, the proportions appear to be, one volume of nitrogen gas to three of *oxygen gas.**

Caroline. Ammonia, therefore, has not, like the two other alkalies, a metallic basis?

Mrs. B. It is believed that it has, though it is extremely difficult to reconcile that idea with what I have just stated of its chemical nature. But the fact is, that although this supposed metallic basis of ammonia has never been obtained distinct and separate, yet both Professor Berzelius, of Stockholm, and Sir H. Davy, have succeeded in forming a combination of mercury with the basis of ammonia, which has so much the appearance of an amalgam, that it strongly corroborates the idea of ammonia having a metallic basis.† But these theoretical points are full of difficulties and doubts, and it would be useless to dwell any longer upon them.

Let us therefore return to the properties of volatile alkali. Ammoniacal gas is considerably lighter than oxygen gas, and only about half the weight of atmospherical air. It possesses most of the properties of the fixed alkalies; but cannot be of so much use in the arts on account of its volatile nature. It is, therefore, never employed in the manufacture of glass, but it forms soap with oils equally as well as potash and soda; it resembles them likewise in its strong attraction for water; for which reason it can be collected in a receiver over mercury only.

Caroline. I do not understand this?

Mrs. B. Do you recollect the method which we used to collect gases in a glass receiver over water?

Caroline. Perfectly.

Mrs. B. Ammoniacal gas has so strong a tendency to unite with water, that, instead of passing through that fluid, it would be instantaneously absorbed by it. We can therefore neither use water for that purpose, nor any other liquid of which water is a component part; so that, in order to collect this gas, we are obliged to have recourse to mercury, (a liquid which has no action upon it,) and a mercurial bath is used instead of a water bath, such as we employed on former occasions. Water impregnated with this gas is nothing more than the fluid which you mentioned at the beginning of the conversation—hartshorn; it is the ammoniacal gas escaping from the water which gives it so powerful a smell.*

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* It ought to be *hydrogen gas.* C.

† This amalgam is easily obtained, by placing a globule of mercury upon a piece of muriat, or carbonat of ammonia, and electrifying this globule by the Voltaic battery. The globule instantly begins to expand to three or four times its former size, and becomes much less fluid, though without losing its metallic lustre, a change which is ascribed to the metallic basis of ammonia uniting with the mercury. This is an extremely curious experiment.

Emily. But there is no appearance of effervescence in hartshorn.

Mrs. B. Because the particles of gas that rise from the water are too subtle and minute for their effect to be visible.

Water diminishes in density, by being impregnated with ammoniacal gas; and this augmentation of bulk increases its capacity for caloric.

Emily. In making hartshorn, then, or impregnating water with ammonia, heat must be absorbed, and cold produced?

Mrs. B. That effect would take place if it was not counteracted by another circumstance; the gas is liquefied by incorporating with the water, and gives out its latent heat. The condensation of the gas more than counterbalances the expansion of the water; therefore, upon the whole, heat is produced.—But if you dissolve ammoniacal gas with ice or snow, cold is produced.—Can you account for that?

Emily. The gas, in being condensed into a liquid, must give out heat; and, on the other hand, the snow or ice, in being rarefied into a liquid, must absorb heat; so that, between the opposite effects, I should have supposed the original temperature would have been preserved.

Mrs. B. But you have forgotten to take into the account the rarefaction of the water (or melted ice) by the impregnation of the gas; and this is the cause of the cold which is ultimately produced.

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* To obtain ammoniacal gas, mix together equal parts of muriate of ammonia, and dry burnt lime; after pulverizing each separately, rub them together in a mortar; put them into a retort and apply the heat of a lamp. Or, the common spirit of sal. ammoniac may be heated in a retort in the same way. To collect and retain the gas without a mercurial bath, fix a receiver or bottle in an inverted position, and connect to the retort a tube, which introduce up into the receiver so that it nearly reaches the bottom. As the gas comes over, its levity is such, that it fills the upper part of the receiver first, gradually driving out the air, and taking its place. To keep it for any considerable time, the receiver must be stopped. A pretty experiment may be made by introducing up into the receiver with the ammonia, some *muriatic gas.* Both gases are invisible until they are brought together, when they unite, forming a dense white cloud, and fall down in the solid form of *muriate* of *ammonia.* The muriatic gas is obtained by pouring sulphuric acid on common salt, and applying the heat of a lamp. It may be sent up into the receiver in the way above described or ammonia. C.

Caroline. Is the *sal volatile* (the smell of which so strongly resembles hartshorn) likewise a preparation of ammonia?

Mrs. B. It is carbonat of ammonia dissolved in water; and which, in its concrete state, is commonly called salts of hartshorn. Ammonia is caustic, like the fixed alkalies, as you may judge by the pungent effects of hartshorn, which cannot be taken internally, nor applied to delicate external parts, without being plentifully diluted with water.—Oil and acids are very excellent antidotes for alkaline poisons; can you guess why?

Caroline. Perhaps, because the oil combines with the alkali, and forms soap, and thus destroys its caustic properties; and the acid converts it into a compound salt, which, I suppose, is not so pernicious as caustic alkali.

Mrs. B. Precisely so.

Ammoniacal gas, if it be mixed with atmospherical air, and a burning taper repeatedly plunged into it, will burn with a large flame of a pecular yellow colour.

Emily. But pray tell me, can ammonia be procured from this Lybian salt only?

Mrs. B. So far from it, that it is contained in, and may be extracted from, all animal substances whatever. Hydrogen and nitrogen are two of the chief constituents of animal matter; it is therefore not surprising that they should occasionally meet and combine in those proportions that compose ammonia. But this alkali is more frequently generated by the spontaneous decomposition of animal substances; the hydrogen and nitrogen gases that arise from putrified bodies combine, and form the volatile alkali.

Muriat of ammonia, instead of being exclusively brought from Lybia, as it originally was, is now chiefly prepared in Europe, by chemical processes. Ammonia, although principally extracted from this salt, can also be produced by a great variety of other substances. The horns of cattle, especially those of deer, yield it in abundance, and it is from this circumstance that a solution of ammonia in water has been called hartshorn. It may likewise be procured from wool, flesh and bones; in a word, any animal substance whatever yields it by decomposition.

We shall now lay aside the alkalies, however important the subject may be, till we treat of their combination with acids. The next time we meet we shall examine the earths.

CONVERSATION XV.

ON EARTHS.

Mrs. B. THE EARTHS, which we are to-day to examine, are nine in number:

SILEX,
ALUMINE,
BARYTES,*
LIME,*
MAGNESIA,*
STRONTITES,*
YTTRIA,
GLUCINA,
ZIRCONIA.

The last three are of late discovery; their properties are but imperfectly known; and, as they have not yet been applied to use, it will be unnecessary to enter into any particulars respecting them; we shall confine our remarks, therefore to the first five. They are composed, as you have already learnt, of a metallic basis combined with oxygen; and, from this circumstance, are incombustible.

Caroline. Yet I have seen turf burnt in the country, and it makes an excellent fire; the earth becomes red hot, and produces a very great quantity of heat.

Mrs. B. It is not the earth that burns, my dear, but the roots, grass, and other remnants of vegetables that are intermixed with it. The caloric, which is produced by the combustion of these substances, makes the earth red hot, and this being a bad conductor of heat, retains its caloric a long time; but were you to examine it when cooled, you would find that it had not absorbed one particle of oxygen, nor suffered any alteration from the fire. Earth is, however, from the circumstance just mentioned, an excellent radiator of heat, and owes its utility, when mixed with fuel, solely to that property. It is in this point of view that Count Rumford has recommended balls of incombustible substances to be arranged in fire-places, and mixed with the coals, by which means the caloric disengaged by the combustion of the latter is more perfectly reflected into the room, and an expense of fuel is saved.

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* There is less evidence that these four earths are composed of metallic bases than there is in the case of ammonia, which it will be remembered was *supposed* to have formed an amalgam with mercury, and on this account was *supposed* to have had a metallic basis. Of the other earths, no one except Dr. Clarke of Cambridge, Eng. has pretended to offer any but *conjectural evidence* of their metallic nature. This gentleman, on subjecting them to the heat of the blow-pipe, charged with oxygen and hydrogen, was led to believe he had obtained their metallic bases. But as his experiments have been repeated at the Royal Institution without success, it is now understood that the Dr. must have been *mistaken*. C.

Emily. I expected that the list of earths would be much more considerable. When I think of the great variety of soils, I am astonished that there is not a greater number of earths to form them.

Mrs. B. You might indeed, almost confine that number to four; for barytes, strontites, and the others of late discovery, act but so small a part in this great theatre, that they cannot be reckoned as essential to the general formation of the globe. And you must not confine your idea of earths to the formation of soil; for rock, marble, chalk, slate, sand, flint, and all kinds of stones, from the precious jewels to the commonest pebbles; in a word, all the immense variety of mineral products may be referred to some of these earths, either in a simple state, or combined the one with the other, or blended with other ingredients.

Caroline. Precious stones composed of earth! That seems very difficult to conceive.

Emily. Is it more extraordinary than that the most precious of all jewels, diamond, should be composed of carbon? But diamond forms an exception, Mrs. B.; for, though a stone, it is not composed of earth.

Mrs. B. I did not specify the exception, as I knew you were so well a quainted with it. Besides, I would call a diamond a mineral rather than a stone, as the latter term always implies the presence of some earth.

Caroline. I cannot conceive how such coarse materials can be converted into such beautiful productions.

Mrs. B. We are very far from understanding all the secret resources of nature; but I do not think the spontaneous formation of the crystals, which we call precious stones, one of the most difficult phenomena to comprehend.

By the slow and regular work of ages, perhaps of hundreds of ages, these earths may be gradually dissolved by water, and as gradually deposited by their solvent in the undisturbed process of crystallisation. The regular arrangement of their particles, during their re-union in a solid mass, gives them that brilliancy, transparency, and beauty, for which they are so much admired; and renders them in appearance so totally different from their rude and primitive ingredients.

Caroline. But how does it happen that they are spontaneously dissolved, and afterwards crystallised?

Mrs. B. The scarcity of many kinds of crystals, as rubies, emeralds, topazes, &c. shows that their formation is not an operation very easily carried on in nature. But cannot you imagine that when water, holding in solution some particles of earth, filters through the crevices of hills or mountains, and at length dribbles into some cavern, each successive drop may be slowly evaporated, leaving behind it the particle of earth which it held in solution? You know that crystallisation is more regular and perfect, in proportion as the evaporation of the solvent is slow and uniform; nature, therefore, who knows no limit of time, has, in all works of this kind, an infinite advantage over any artist who attempts to imitate such productions.

Emily. I can now conceive that the arrangement of the particles of earth, during crystallisation, may be such as to occasion transparency, by admitting a free passage to the rays of light; but I cannot understand why crystallised earths should assume such beautiful colours as most of them do. Sapphire, for instance, is of a celestial blue; ruby, a deep red; topaz, a brilliant yellow?

Mrs. B. Nothing is more simple than to suppose that the arrangement of their particles is such, as to transmit some of the coloured rays of light, and to reflect others, in which case the stone must appear of the colour of the rays which it reflects. But besides, it frequently happens that the colour of a stone is owing to a mixture of some metallic matter.

Caroline. Pray, are the different kinds of precious stones each composed of one individual earth, or are they formed of a combination of several earths?

Mrs. B. A great variety of materials enters into the composition of most of them; not only several earths, but sometimes salts and metals. The earths, however, in their simple state, frequently form very beautiful crystals; and, indeed, it is in that state only that they can be obtained perfectly pure.

Emily. Is not the Derbyshire spar produced by the crystallisation of earths, in the way you have just explained? I have been in some of the subterraneous caverns where it is found, which are similar to those you have described.

Mrs. B. Yes; but this spar is a very imperfect specimen of crystallisation;* it consists of a variety of ingredients confusedly bleded together, as you may judge by its opacity, and by the various colours and appearances which it exhibits.

But, in examining the earths in their most perfect and agreeable form, we must not lose sight of that state in which they are commonly found, and which, if less pleasing to the eye, is far more interesting by its utility.

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* The Derbyshire spar is composed of *lime* and *fluoric* acid: hence it is called *fluate* of *lime*. The colours are owing to intermixture with metallic oxides. It is a very beautiful mineral, and instead of being opake it is generally translucent, or nearly transparent. C.

All the earths are more or less endowed with alkaline properties; but there are four, barytes, magnesia, lime, and strontites, which are called *alkaline earths*, because they possess those qualities in so great a degree, as to entitle them, in most respects, to the rank of alkalies. They combine and form compound salts with acids, in the same way as alkalies; they are, like them, susceptible of a considerable degree of causticity, and are acted upon in a similar manner by chemical tests.—The remaining earths, silex and alumine, with one or two others of late discovery, are in some degree more earthy, that is to say, they possess more completely the properties common to all the earths, which are, insipidity, dryness, unalterableness in the fire, infusibility, &c.

Caroline. Yet, did you not tell us that silex, or siliceous earth, when mixed with an alkali, was fusible, and run into glass?

Mrs. B. Yes, my dear; but the characteristic properties of earths, which I have mentioned, are to be considered as belonging to them in a state of purity only; a state in which they are very seldom to be met with in nature.—Besides these general properties, each earth has its own specific characters, by which it is distinguished from any other substance.—Let us therefore review them separately.

SILEX, or SILICA, abounds in flint, sand, sand-stone, agate, jasper, &c.; it forms the basis of many precious stones, and particularly of those which strike fire with steel. It is rough to the touch, scratches and wears away metals; it is acted upon by no acid but the fluoric, and is not soluble in water by any known process; but nature certainly dissolves it by means with which we are unacquainted, and thus produces a variety of siliceous crystals, and amongst these *rock crystal*, which is the purest specimen of this earth. Silex appears to have been intended by Providence to form the solid basis of the globe, to serve as a foundation for the original mountains, and give them that hardness and durability which has enabled them to resist the various revolutions which the surface of the earth has successively undergone. From these mountains siliceous rocks have, during the course of ages, been gradually detached by torrents of water, and brought down in fragments; these, in the violence and rapidity of their descent, are sometimes crumbled to sand, and in this state form the beds of rivers and of the sea, chiefly composed of siliceous materials. Sometimes the fragments are broken without being pulverised by their fall, and assume the form of pebbles, which gradually become rounded and polished.

Emily. Pray what is the true colour of silex, which forms such a variety of different coloured substances? Sand is brown, flint is nearly black, and precious stones are of all colours.

Mrs. B. Pure silex, such as is found only in the chemist's laboratory, is perfectly white, and the various colours which it assumes, in the different substances you have just mentioned, proceed from the different ingredients with which it is mixed in them.

Caroline. I wonder that silex is not more valuable, since it forms the basis of so many precious stones.*

Mrs. B. You must not forget that the value we set upon precious stones depends in a great measure upon the scarcity with which nature affords them; for, were those productions either common or perfectly imitable by art, they would no longer, notwithstanding their beauty, be so highly esteemed. But the real value of siliceous earth, in many of the most useful arts, is very extensive. Mixed with clay, it forms the basis of all the various kinds of earthern ware, from the most common utensils to the most refined ornaments.

Emily. And we must recollect its importance to the formation of glass with potash.

Mrs. B. Nor should we omit to mention, likewise, many other important uses of silex, such as being the chief ingredient of some of the most durable cements, of mortar, &c.

I said before that siliceous earth combined with no acid but the fluoric; it is for this reason that glass is liable to be attacked by that acid only, which, from its strong affinity for silex, forces that substance from its combination with the potash, and thus destroys the glass.

We will now hasten to proceed to the other earths, for I am rather apprehensive of your growing weary of this part of our subject.

Caroline. I confess that the history of the earths is not quite so entertaining as that of the simple substances.

Mrs. B. Perhaps not; but it is absolutely indispensable that you should know something of them; for they form the basis of so many interesting and important compounds, that their total omission would throw great obscurity on our general outline of chemical science. We shall, however, review them in as cursory a manner as the subject can admit of.

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* The bases of some of the most costly gems, as sapphire, ruby and topaz, are alumine. C.

Alumine derives its name from a compound salt called *alum*, of which it forms the basis.

Caroline. But it ought to be just the contrary, Mrs. B.; the simple body should give, instead of taking, its name from the compound.

Mrs. B. That is true; but as the compound salt was known long before its basis was discovered, it was very natural that when the earth was at length separated from the acid, it should derive its name from the compound from which it was obtained. However, to remove your scruples, we will call the salt according to the new nomenclature, *sulphat of alumine.* From this combination, alumine may be obtained in its pure state; it is then soft to the touch, makes a paste with water, and hardens in the fire. In nature, it is found chiefly in clay, which contains a considerable proportion of this earth; it is very abundant in fuller's earth, slate, and a variety of other mineral productions. There is indeed scarcely any mineral substance more useful to mankind than alumine. In the state of clay, it forms large strata of the earth, gives consistency to the soil of valleys, and of all low and damp spots, such as swamps and marshes. The beds of lakes, ponds, and springs, are almost entirely of clay; instead of allowing of the filtration of water, as sand does, it forms an impenetrable bottom, and by this means water is accumulated in the caverns of the earth, producing those reservoirs whence springs issue, and spout out at the surface.

Emily. I always thought that these subterraneous reservoirs of water were bedded by some hard stone, or rock, which the water could not penetrate.

Mrs. B. That is not the case; for in the course of time water would penetrate, or wear away silex, or any other kind of stone, while it is effectually stopped by clay, or alumine.

The solid compact soils, such as are fit for corn, owe their consistence in a great measure to alumine; this earth is therefore used to improve sandy or chalky soils, which do not retain a sufficient quantity of water for the purpose of vegetation.

Alumine is the most essential ingredient in all potteries. It enters into the composition of brick, as well as that of the finest porcelain: the addition of silex and water hardens it, renders it susceptible of a degree of vitrification, and makes it perfectly fit for its various purposes.

Caroline. I can scarcely conceive that brick and china should be made of the same materials.

Mrs. B. Brick consists almost entirely of baked clay; but a certain proportion of silex is essential to the formation of earthen or stone ware. In common potteries sand is used for that purpose; a more pure silex is,* I believe, necessary for the composition of porcelain, as well as a finer kind of clay; and these materials are, no doubt, more carefully prepared, and curiously wrought, in the one case than in the other. Porcelain owes its beautiful semi-transparency to a commencement of vitrification.

Emily. But the commonest earthen-ware, though not transparent, is covered with a kind of glazing.

Mrs. B. That precaution is equally necessary for use as for beauty, as the ware would be liable to be spoiled and corroded by a variety of substances, if not covered with a coating of this kind. In porcelain it consists of enamel, which is a fine white opaque glass, formed of metallic oxyds, sand, salts, and such other materials as are susceptible of vitrification. The glazing of common earthen-ware is made chiefly of oxyd of lead, or sometimes merely of salt, which, when thinly spread over earthen vessels, will, at a certain heat, run into opaque glass.

Caroline. And of what nature are the colours which are used for painting porcelain?

Mrs. B. They are all composed of metallic oxyds, so that these colours, instead of receiving injury from the application of fire, are strengthened and developed by its action, which causes them to undergo different degrees of oxydation.

Alumine and silex are not only often combined by art, but they have in nature a very strong tendency to unite, and are found combined, in different proportions, in various gems and other minerals. Indeed, many of the precious stones, such as ruby, oriental sapphire, amethyst,† &c. consist chiefly of alumine.

We may now proceed to the alkaline earths. I shall say but a few words on BARYTES, as it is hardly ever used, except in chemical laboratories. It is remarkable for its great weight, and its strong alkaline properties, such as destroying animal substances, turning green some blue vegetable colours, and showing a powerful attraction for acids; this last property it possesses to such a degree, particularly with regard to the sulphuric acid, that it will always detect its presence in any substance or combination whatever, by immediately uniting with it, and forming a sulphat of barytes. This renders it a very valuable chemical test. It is found pretty abundantly in nature in the state of carbonat,* from which the pure earth can be easily separated.

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* Porcelain clay, of which china ware is made, is found among granite rocks, and seems to owe its origin to the decomposition of a mineral called *feldspar.* Its composition is silex and alumine, silex being the predominant ingredient. C.

† The amethyst is almost entirely composed of silex. C.

The next earth we have to consider is LIME. This is a substance of too great and general importance to be passed over so slightly as the last.

Lime is strongly alkaline. In nature it is not met with in its simple state, as its affinity for water and carbonic acid is so great, that it is always found combined with these substances, with which it forms the common lime-stone; but it is separated in the kiln from these ingredients, which are volatilised whenever a sufficient degree of heat is applied.

Emily. Pure lime, then, is nothing but lime-stone, which has been deprived, in the kiln, of its water and carbonic acid?

Mrs. B. Precisely: in this state it is called *quick-lime*, and it is so caustic, that it is capable of decomposing the dead bodies of animals very rapidly, without their undergoing the process of putrefaction.—I have here some quick-lime, which is kept carefully corked up in a bottle, to prevent the access of air; for were it all exposed to the atmosphere, it would absorb both moisture and carbonic acid gas from it, and be soon slaked. Here is also some lime-stone—we shall pour a little water on each, and observe the effects that result from it.

Caroline. How the quick-lime hisses! It is become excessively hot!—It swells, and now it bursts and crumbles to powder, while the water appears to produce no kind of alteration on the lime-stone.

Mrs. B. Because the lime-stone is already saturated with water, whilst the quick-lime, which has been deprived of it in the kiln, combines with it with very great avidity, and produces this prodigious disengagement of heat, the cause of which I formerly explained to you; do you recollect it?

Emily. Yes; you said that the heat did not proceed from the lime, but from the water which was *solidified*, and thus parted with its heat of liquidity.

Mrs. B. Very well. If we continue to add successive quantities of water to the lime after being slaked and crumbled as you see, it will then gradually be diffused in the water, till it will at length be dissolved in it, and entirely disappear; but for this purpose it requires no less than 700 times its weight of water. This solution is called *lime water*.*

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* The native *carbonate* of barytes is a rare mineral. It is a virulent poison. The *sulphate* of barytes is found in considerable abundance. C.

Caroline. How very small, then, is the proportion of lime dissolved!

Mrs. B. Barytes is still of more difficult solution; it dissolves only in 900 times its weight of water; but it is much more soluble in the state of crystals. The liquid contained in this bottle is lime-water; it is often used as a medicine, chiefly, I believe, for the purpose of combining with, and neutralising, the superabundant acid which it meets with in the stomach.

Emily. I am surprised that it is so perfectly clear; it does not at all partake of the whiteness of the lime.

Mrs. B. Have you forgotten that, in solutions, the solid body is so minutely subdivided by the fluid as to become invisible, and therefore will not in the least degree impair the transparency of the solvent?

I said that the attraction of lime for carbonic acid was so strong, that it would absorb it from the atmosphere. We may see this effect by exposing a glass of lime-water to the air; the lime will then separate from the water, combine with the carbonic acid, and re-appear on the surface in the form of a white film, which is carbonat of lime, commonly called *chalk*.

Caroline. Chalk is, then, a compound salt! I never should have supposed that those immense beds of chalk, that we see in many parts of the country, were a salt.—Now, the white film begins to appear on the surface of the water; but it is far from resembling hard solid chalk.

Mrs. B. That is owing to its state of extreme division; in a little time it will collect into a more compact mass, and subside at the bottom of the glass.

If you breathe into lime-water, the carbonic acid, which is mixed with the air that you expire, will produce the same effect. It is an experiment very easily made;—I shall pour some lime-water into this glass tube, and, by breathing repeatedly into it, you will soon perceive a precipitation of chalk—

Emily. I see already a small white cloud formed.

Mrs. B. It is composed of minute particles of chalk; at present it floats in the water, but it will soon subside.

Carbonat of lime, or chalk, you see, is insoluble in water, since the lime which was dissolved re-appears when converted into chalk; but you must take notice of a very singular circumstance, which is, that chalk is soluble in water impregnated with carbonic acid.

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* To make lime water, take a piece of well burned lime about the size of a hen's egg, put it into an earthen dish, and sprinkle water on it, till it falls into powder: Then pour on two quarts of boiling water, and stir it several times, after the lime has settled; pour off the clear water and cork it up for use. C.

Caroline. It is very curious, indeed, that carbonic acid gas should render lime soluble in one instance, and insoluble in the other!

Mrs. B. I have here a bottle of Seltzer water, which, you know, is strongly impregnated with carbonic acid:—let us pour a little of it into a glass of lime-water. You see that it immediately forms a precipitation of carbonat of lime?

Emily. Yes, a white cloud appears.

Mrs. B. I shall now pour an additional quantity of the Seltzer water into the lime-water—

Emily. How singular! The cloud is re-dissolved, and the liquid is again transparent.

Mrs. B. All the mystery depends upon this circumstance, that carbonat of lime is soluble in carbonic acid, whilst it is insoluble in water; the first quantity of carbonic acid, therefore, which I introduced into the lime-water, was employed in forming the carbonat of lime, which remained visible, until an additional quantity of carbonic acid dissolved it. Thus, you see, when the lime and carbonic acid are in proper proportions to form chalk, the white cloud appears, but when the acid predominates, the chalk is no sooner formed than it is dissolved.

Caroline. That is now the case; but let us try whether a further addition of lime-water will again precipitate the chalk.

Emily. It does, indeed! The cloud re-appears, because, I suppose, there is now no more of the carbonic acid than is necessary to form chalk; and, in order to dissolve the chalk, a superabundance of acid is required.

Mrs. B. We have, I think, carried this experiment far enough; every repetition would but exhibit the same appearances.

Lime combines with most of the acids, to which the carbonic (as being the weakest) readily yields it; but these combinations we shall have an opportunity of noticing more particularly hereafter. It unites with phosphorus, and with sulphur, in their simple state; in short, of all the earths, lime is that which nature employs most frequently, and most abundantly, in its innumerable combinations. It is the basis of all calcareous earths and stones; we find it likewise in the animal and the vegetable creations.

Emily. And in the arts is not lime of very great utility?

Mrs. B. Scarcely any substance more so; you know that it is a most essential requisite in building, as it constitutes the basis of all cements, such as mortar, stucco, plaster, &c.

Lime is also of infinite importance in agriculture; it lightens and warms soils that are too cold and compact, in consequence of too great a proportion of clay.—But it would be endless to enumerate the various purposes for which it is employed; and you know enough of it to form some idea of its importance; we shall, therefore, now proceed to the third alkaline earth, MAGNESIA.

Caroline. I am already pretty well acquainted with that earth; it is a medicine.

Mrs. B. It is in the state of carbonat that magnesia is usually employed medicinally; it then differs but little in appearance from its simple form, which is that of a very fine light white powder. It dissolves in 2000 times its weight of water, but forms with acids extremely soluble salts It has not so great an attraction for acids as lime, and consequently yields them to the latter. It is found in a great variety of mineral combinations, such as slate, mica, and amianthus, and more particularly in a certain lime-stone, which has lately been discovered by Mr. Tennant to contain it in very great quantities. It does not attract and solidify water, like lime: but when mixed with water and exposed to the atmosphere, it slowly absorbs carbonic acid from the latter, and thus loses its causticity. Its chief use in medicine is, like that of lime, derived from its readiness to combine with, and neutralise, the acid which it meets with in the stomach.

Emily. Yet, you said that it was taken in the state of carbonat, in which case it has already combined with an acid?

Mrs. B. Yes; but the carbonic is the last of all the acids in the order of affinities; it will therefore yield the magnesia to any of the others. It is, however, frequently taken in its caustic state as a remedy for flatulence. Combined with sulphuric acid, magnesia forms another and more powerful medicine, commonly called *Epsom salt.*

Caroline. And properly, *sulphat of magnesia,* I suppose? Pray why was it ever called Epsom salt?

Mrs. B. Because there is a spring in the neighbourhood of Epsom which contains this salt in great abundance.

The last alkaline earth which we have to mention is STRONTIAN, or STRONTITES, discovered by Dr. Hope a few years ago. It so strongly resembles barytes in its properties, and is so sparingly found in nature, and of so little use in the arts, that it will not be necessary to enter into any particulars respecting it. One of the remarkable characteristic properties of strontites is, that its salts, when dissolved in spirit of wine, tinge the flame of a deep red, or blood colour.

CONVERSATION XVI.

ON ACIDS.

Mrs. B. We may now proceed to the acids. Of the metallic oxyds, you have already acquired some general notions. This subject, though highly interesting in its details, is not of sufficient importance to our concise view of chemistry, to be particularly treated of; but it is absolutely necessary that you should be better acquainted with the acids, and likewise with their combinations with the alkalies, which form the triple compounds called NEUTRAL SALTS.

The class of acids is characterised by very distinct properties. They all change blue vegetable infusions to a red colour: they are all more or less sour to the taste; and have a general tendency to combine with the earths, alkalies, and metallic oxyds.

You have, I believe, a clear idea of the nomenclature by which the base (or radical) of the acid, and the various degrees of acidification, are expressed?

Emily. Yes, I think so; the acid is distinguished by the name of its base, and its degree of oxydation, that is, the quantity of oxygen it contains, by the termination of that name in *ous* or *ic;* thus sulphure*ous* acid is that formed by the smallest proportion of oxygen combined with sulphur; sulphur*ic* acid is that which results from the combination of sulphur with the greatest quantity of oxygen.

Mrs. B. A still greater latitude may, in many cases, be allowed to the proportions of oxygen that can be combined with acidificiable radicals; for several of these radicals are susceptible of uniting with a quantity of oxygen so small as to be insufficient to give them the properties of acids: in these cases, therefore, they are converted into oxyds. Such is sulphur, which by exposure to the atmosphere with a degree of heat inadequate to produce inflammation, absorbs a small proportion of oxygen, which colours it red or brown. This, therefore, is the first degree of oxygenation of sulphur; the 2d converts it into sulphur*ous* acid; the 3d into the sulphur*ic* acid; and 4thly, if it was found capable of combining with a still larger proportion of oxygen, it would then be termed *super-oxygenated sulphuric acid.*

Emily. Are these various degrees of oxygenation common to all the acids?

Mrs. B. No; they vary much in this respect: some are susceptible of only one degree of oxygenation; others, of two, or three; there are but very few that will admit of more.

Caroline. The modern nomenclature must be of immense advantage in pointing out so easily the nature of the acids, and their various degrees of oxygenation.

Mrs. B. Till lately many of the acids had not been decomposed; but analogy afforded so strong a proof of their compound nature, that I never could reconcile myself to classing them with the simple bodies, though this division has been adopted by several chemical writers. At present there are only the muriatic and the fluoric acids, which have not had their bases distinctly separated.

Caroline. We have heard of a great variety of acids; pray how many are there in all?

Mrs. B. I believe there are reckoned at present thirty-four, and their number is constantly increasing, as the science improves; but the most important, and those to which we shall almost entirely confine our attention, are but few. I shall, however, give you a general view of the whole; and then we shall more particularly examine those that are the most essential.

This class of bodies was formerly divided into mineral, vegetable, and animal acids, according to the substances from which they were commonly obtained.

Caroline. That, I should think, must have been an excellent arrangement; why was it altered?

Mrs. B. Because in many cases it produced confusion. In which class, for instance, would you place carbonic acid?

Caroline. Now I see the difficulty. I should be at a loss where to place it, as you have told us that it exists in the animal, vegetable, and mineral kingdoms.

Emily. There would be the same objection with respect to phosphoric acid, which, though obtained chiefly from bones, can also, you said, be found in small quantities in stones, and likewise in some plants.

Mrs. B. You see, therefore, the propriety of changing this mode of classification. These objections do not exist in the present nomenclature; for the composition and nature of each individual acid is in some degree pointed out, instead of the class of bodies from which it is extracted; and, with regard to the more general division of acids, they are classed under these three heads:

First, Acids of known or supposed simple bases, which are formed by the union of these bases with oxygen. They are the following:

The *Sulphuric*
Carbonic
Nitric
Phosphoric
Arsenical
Tungstenic
Molybdenic
Boracic
Fluoric
Muriatic

Acids, of known and simple bases.

This class comprehends the most anciently known and most important acids. The sulphuric, nitric, and muriatic were formerly, and are still frequently, called *mineral acids.*

2dly, Acids that have double or binary radicals, and which consequently consist of triple combinations. These are the vegetable acids, whose common radical is a compound of hydrogen and carbon.

Caroline. But if the basis of all the vegetable acids be the same, it should form but one acid; it may indeed combine with different proportions of oxygen, but the nature of the acid must be the same.

Mrs. B. The only difference that exists in the basis of vegetable acids, is the various proportions of hydrogen and carbon from which they are severally composed. But this is enough to produce a number of acids apparently very dissimilar. That they do not, however, differ essentially, is proved by their susceptibility of being converted into each other, by the addition or subtraction of a portion of hydrogen or of carbon. The names of these acids are,

The *Acetic*
Oxalic
Tartarous
Citric
Malic
Gallic
Mucous
Benzoic
Succinic
Camphoric
Suberic

Acids, of double bases, being of vegetable orgin.

The 3d class of acids consists of those which have triple radicals, and are therefore of a still more compound nature. This class comprehends the animal acids, which are,

The *Lactic*
Prussic
Formic
Bombic } Acids, of triple bases, or animal acids.
Sebacic
Zoonic
Lithic

I have given you this summary account or enumeration of the acids, as you may find it more satisfactory to have at once an outline or a general notion of the extent of the subject; but we shall now confine ourselves to the first class, which requires our more immediate attention; and defer the few remarks which we shall have to make on the others, till we treat of the chemistry of the animal and vegetable kingdoms.

The acids of simple and known radicals are all capable of being decomposed by combustible bodies, to which they yield their oxygen. If, for instance, I pour a drop of sulphuric acid on this piece of iron, it will produce a spot of rust, you know what that is?

Caroline. Yes; it is an oxyd, formed by the oxygen of the acid combining with the iron.

Mrs. B. In this case you see the sulphur deposits the oxygen by which it was acidified on the metal. And again, if we pour some acid on a compound combustible substance, (we shall try it on this piece of wood,) it will combine with one or more of the constituents of that substance, and occasion a decomposition.

Emily. It has changed the colour of the wood to black. How is that?

Mrs. B. The oxygen deposited by the acid has burnt it; you know that wood in burning becomes black before it is reduced to ashes. Whether it derives the oxygen which burns it from the atmosphere, or from any other source, the chemical effect on the wood is the same. In the case of real combustion, wood becomes black, because it is reduced to the state of charcoal by the evaporation of its other constituents. But can you tell me the reason why wood turns black when burnt by the application of an acid?

Caroline. First, tell me what are the ingredients of wood?

Mrs. B. Hydrogen and carbon are the chief constitutes of wood, as of all other vegetable substances.

Caroline. Well, then, I suppose that the oxygen of the acid combines with the hydrogen of the wood, to form water; and that the carbon of the wood, remaining alone, appears of its usual black colour.

Mrs. B. Very well indeed, my dear; that is certainly the most plausible explanation.

Caroline. Would not this be a good method of making charcoal?

Mrs. B. It would be an extremely expensive, and, I believe, very imperfect method; for the action of the acid on the wood, and the heat produced by it, are far from sufficient to deprive the wood of all its evaporable parts.

Caroline. What is the reason that vinegar, lemon, and the acid of fruits, do not produce this effect on wood?

Mrs. B. They are vegetabe acids, whose bases are composed of hydrogen and carbon; the oxygen, therefore, will not be disposed to quit this radical, where it is already united with hydrogen. The strongest of these may, perhaps, yield a little of their oxygen to the wood, and produce a stain upon it; but the carbon will not be sufficiently uncovered to assume its black colour. Indeed, the several mineral acids themselves possess this power of charring wood in very different degrees.

Emily. Cannot vegetable acids be decomposed, by any combustibles?

Mrs. B. No; because their radical is composed of two substances which have a greater attraction for oxygen than any known body.

Caroline. And are those strong acids, which burn and decompose wood, capable of producing similar effects on the skin and flesh of animals?

Mrs. B. Yes; all the mineral acids, and one of them more especially, possess powerful caustic qualities. They actually corrode and destroy the skin and flesh; but they do not produce upon these exactly the same alteration they do on wood, probably because there is a great proportion of nitrogen and other substances in animal matter, which prevents the separation of carbon from being so conspicuous.

CONVERSATION XVII.

OF THE SULPHURIC AND PHOSPHORIC ACIDS; OR THE COMBINATION OF OXYGEN WITH SULPHUR AND PHOSPHORUS; AND OF THE SULPHATS AND PHOSPHATS.

Mrs. B. In addition to the general survey which we have taken of acids, I think you will find it interesting to examine individually a few of the most important of them, and likewise some of their principal combination with the alkalies, alkaline earths, and metals. The first of the acids, in point of importance, is the SULPHURIC, formerly called *oil of vitriol.*

Caroline. I have known it a long time by that name, but had no idea that it was the same fluid as sulphuric acid. What resemblance or connection can there be between oil of vitriol and this acid?

Mrs. B. Vitrol is the common name for sulphat of iron, a salt which is formed by the combination of sulphuric acid and iron; the sulphuric acid was formerly obtained by distillation from this salt, and it very naturally received its name from the substance which afforded it.

Caroline. But it is still usually called oil of vitirol?

Mrs. B. Yes; a sufficient length of time has not yet elapsed, since the invention of the new nomenclature, for it to be generally disseminated; but, as it is adopted by all scientific chemists, there is every reason to suppose that it will gradually become universal. When I received this bottle from the chemists, *oil of vitriol* was inscribed on the label; but, as I knew you were very punctilious in regard to the nomenclature, I changed it, and substituted the words *sulphuric acid.*

Emily. This acid has neither colour nor smell, but it appears much thicker than water.

Mrs. B. It is nearly twice as heavy as water, and has, you see, an oily consistence.

Caroline. And it is probably from this circumstance that it has been called an oil, for it can have no real claim to that name, as it does not contain either hydrogen or carbon, which are the essential constituents of oil.

Mrs. B. Certainly; and therefore it would be the more absurd to retain a name which owed its origin to such a mistaken analogy.

Sulphuric acid, in its purest state, would probably be a concrete substance, but its attraction for water is such, that it is impossible to obtain that acid perfectly free from it; it is, therefore, always seen in a liquid form, such as you here find it. One of the most striking properties of sulphuric acid is that of evolving a considerable quantity of heat when mixed with water; this I have already shown you.

Emily. Yes, I recollect it; but what was the degree of heat produced by that mixture?

Mrs. B. The thermometer may be raised by it to 300 degrees, which is considerably above the temperature of boiling water.

Caroline. Then water might be made to boil in that mixture?

Mrs. B. Nothing more easy, provided that you employ sufficient quantities of acid and of water, and in the due proportions. The greatest heat is produced by a mixture of one part of water to four of the acid: we shall make a mixture of these proportions, and immerse in it this thin glass tube, which is full of water.

Caroline. The vessel feels extremely hot, but the water does not boil yet.

Mrs. B. You must allow some time for the heat to penetrate the tube, and raise the temperature of the water to the boiling point—

Caroline. Now it boils—and with increasing violence.

Mrs. B. But it will not continue boiling long; for the mixture gives out heat only while the particles of the water and the acid are mutually penetrating each other: as soon as the new arrangement of those particles is effected, the mixture will gradually cool, and the water return to its former temperature. You have seen the manner in which sulphuric acid decomposes all combustible substances, whether animal, vegetable, or mineral, and burns them by means of its oxygen?

Caroline. I have very unintentionally repeated the experiment on my gown, by letting a drop of the acid fall upon it, and it has made a stain, which, I suppose, will never wash out.

Mrs. B. No, certainly; for before you can put it into water, the spot will become a hole, as the acid has literally burnt the muslin.

Caroline. So it has indeed! Well, I will fasten the stopper, and put the bottle away, for it is a dangerous substance.—Oh, now I have done worse still, for I have spilt some on my hand!

Mrs. B. It is then burned, as well as your gown, for you know that oxygen destroys animal as well as vegetable matters; and, as far as the decomposition of the skin of your finger is effected, there is no remedy; but by washing it immediately in water, you will dilute the acid, and prevent any further injury.

Caroline. It feels extremely hot, I assure you.

Mrs. B. You have now learned, by experience, how cautiously this acid must be used. You will soon become acquainted with another acid, the nitric, which, though it produces less heat on the skin, destroys it still quicker, and makes upon it an indelible stain. You should never handle any substances of this kind, without previously dipping your fingers in water, which will weaken their caustic effects. But, since you will not repeat the experiment, I must put in the stopper, for the acid attracts the moisture from the atmosphere, which would destroy its strength and purity.

Emily. Pray, how can sulphuric acid be extracted from sulphat of iron by distillation?

Mrs. B. The process of distillation, you know, consists in separating substances from one another by means of their different degrees of volatility, and by the introduction of a new chemical agent, caloric. Thus, if sulphat of iron be exposed in a retort to a proper degree of heat, it will be decomposed, and the sulphuric acid will be volatilised.

Emily. But now that the process of forming acids by the combustion of their radicals is known, why should not this method be used for making sulphuric acid?

Mrs. B. This is actually done in most manufactures; but the usual method of preparing sulphuric acid does not consist in burning the sulphur in oxygen gas (as we formerly did by the way of experiment,) but in heating it together with another substance, nitre, which yields oxygen in sufficient abundance to render the combustion in common air rapid and complete.

Caroline. This substance, then, answers the same purpose as oxygen gas?

Mrs. B. Exactly. In manufactures the combustion is performed in a leaden chamber, with water at the bottom, to receive the vapour and assist its condensation. The combustion is, however, never so perfect but that a quantity of *sulphureous* acid is formed at the same time; for you recollect that the sulphureous acid according to the chemical nomenclature, differs from the sulphuric only by containing less oxygen.

From its own powerful properties, and from the various combinations into which it enters, sulphuric acid is of great importance in many of the arts.

It is used also in medicine in a state of great dilution; for were it taken internally, in a concentrated state, it would prove a most dangerous poison.

Caroline. I am sure it would burn the throat and stomach.

phuric acid and potash. This salt is easily soluble in boiling water. Solubility is, indeed, a property common to all salts; and they always produce cold in melting.

Emily. That must be owing to the caloric which they absorb in passing from a solid to a fluid form.

Mrs. B. That is, certainly, the most probable explanation.

Sulphat of soda, commonly called Glauber's salt, is another medicinal salt, which is still more bitter than the preceding. We must prepare some of these compounds, that you may observe the phenomena which take place during their formation. We need only pour some sulphuric acid over the soda which I have put into this glass.

Caroline. What an amazing heat is disengaged!—I thought you said that cold was produced by the melting of salts?

Mrs. B. But you must observe that we are now *making*, not *melting* a salt. Heat is disengaged during the formation of compound salts, and a faint light is also emitted, which may sometimes be perceived in the dark.

Emily. And is this heat and light produced by the union of the two opposite electricities of the alkali and the acid?

Mrs. B. No doubt it is, if that theory be true.

Caroline. The union of an acid and an alkali is then an actual combustion?

Mrs. B. Not precisely, though there is certainly much analogy in these processes.

Caroline. Will this sulphat of soda become solid?

Mrs. B. We have not, I suppose, mixed the acid and the alkali in the exact proportions that are required for the formation of the salt, otherwise the mixture would have been almost immediately changed to a solid mass; but, in order to obtain it in crystals, as you see it in this bottle, it would be necessary first to dilute it with water, and afterwards to evaporate the water, during which operation the salt would gradually crystallise.

Caroline. But of what use is the addition of water, if it is afterwards to be evaporated?

Mrs. B. When suspended in water, the acid and the alkali are more at liberty to act on each other, their union is more complete, and the salt assumes the regular form of crystals during the slow evaporation of its solvent.

Sulphat of soda liquefies by heat, and effloresces in the air.

Emily. Pray what is the meaning of the word *effloresces*? I do not recollect your having mentioned it before.

Mrs. B. A salt is said to effloresce when it loses its water of crystallisation on being exposed to the atmosphere, and is thus gradually converted into a dry powder: you may observe that these crystals of sulphat of soda are far from possessing the transparency which belongs to their crystalline state; they are covered with a white powder, occasioned by their having been exposed to the atmosphere, which has deprived their surface of its lustre, by absorbing its water of crystallisation. Salts are, in general, either *efflorescent* or *deliquescent*; this latter property is precisely the reverse of the former; that is to say, deliquescent salts absorb water from the atmosphere, and are moistened and gradually melted by it. Muriat of lime is an instance of great deliquescence.

Emily. But are there no salts that have the same degree of attraction for water as the atmosphere, and that will consequently not be affected by it?

Mrs. B. Yes; there are many such salts, as, for instance, common salt, sulphat of magnesia, and a variety of others.

Sulphat of lime is very frequently met with in nature, and constitutes the well-known substance called *gypsum*, or *plaster of Paris*.

Sulphat of magnesia, commonly called *Epsom salt*, is another very bitter medicine, which is obtained from sea-water and from several springs, or may be prepared by the direct combination of its ingredients.

We have formerly mentioned *sulphat of alumine* as constituting the common *alum*; it is found in nature chiefly in the neighbourhood of volcanoes, and is particularly useful in the arts, from its strong astringent qualities. It is chiefly employed by dyers and calico-printers, to fix colours; and is used also in the manufacture of some kinds of leather.

Sulphuric acid combines also with the metals.

Caroline. One of these combinations, *Sulphat of iron*, we are already well acquainted with.

Mrs. B. That is the most important metallic salt formed by sulphuric acid, and the only one that we shall here notice. It is of great use in the arts; and, in medicine, it affords a very valuable tonic: it is of this salt that most of those preparations called *steel medicines* are composed.

Caroline. But does any carbon enter into these compositions to form steel?

Mrs. B. Not an atom: they are, therefore, very improperly called steel: but it is the vulgar appellation; and medical men themselves often comply with the general custom.

Sulphat of iron may be prepared, as you have seen, by dissolving iron in sulphuric acid; but it is generally obtained from the natural production called *Pyrites*, which being a sulphuret of iron, requires only exposure to the atmosphere to be oxydated, in order to form the salt; this, therefore, is much the most easy way of procuring it on a large scale.

Emily. I am surprised to find that both acids and compound salts are generally obtained from their various combinations, rather than from the immediate union of their ingredients.

Mrs. B. Were the simple bodies always at hand, their combinations would naturally be the most convenient method of forming compounds; but you must consider that, in most instances, there is great difficulty and expense in obtaining the simple ingredients from their combinations; it is, therefore often more expedient to procure compounds from the decomposition of other compounds. But, to return to the sulphat of iron.—There is a certain vegetable acid called *Gallic acid*, which has the remarkable property of precipitating this salt black—I shall pour a few drops of the gallic acid into this solution of sulphat of iron—

Caroline. It is become as black as ink!

Mrs. B. And it is ink in reality. Common writing ink is a precipitate of sulphat of iron by gallic acid; the black colour is owing to the formation of gallat of iron, which being insoluble, remains suspended in the fluid.

This acid has also the property of altering the colour of iron in its metallic state. You may frequently see its effect on the blade of a knife, that has been used to cut certain kinds of fruits.

Caroline. True; and that is, perhaps, the reason that a silver knife is preferred to cut fruits; the gallic acid, I suppose, does not act upon silver.—Is this acid found in all fruits?

Mrs. B. It is contained, more or less, in the rind of most fruits and roots, especially the radish, which, if scraped with a steel or iron knife, has its bright red colour changed to a deep purple, the knife being at the same time blackened. But the vegetable substance in which the gallic acid most abounds is *nutgall*, a kind of excrescence that grows on oaks, and from which the acid is commonly obtained for its various purposes.

Mrs. B. We now come to the PHOSPHORIC and PHOSPHOROUS ACIDS. In treating of phosphorus, you have seen how these acids may be obtained from it by combustion?

Emily. Yes; but I should be much surprised if it was the usual method of obtaining them, since it is so very difficult to procure phosphorus in its pure state.

Mrs. B. You are right, my dear; the phosphoric acid, for general purposes, is extracted from bones, in which it is contained in the state of phosphat of lime; from this salt the phosphoric acid is separated by means of the sulphuric, which combines with the lime. In its pure state, phosphoric acid is either liquid or solid, according to its degree of concentration.

Among the salts formed by this acid, *phosphat of lime* is the only one that affords much interest; and this, we have already observed, constitutes the basis of all bones. It is also found in very small quantities in some vegetables.

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CONVERSATION XVIII.

OF THE NITRIC AND CARBONIC ACIDS; OR THE COMBINATIONS OF OXYGEN WITH NITROGEN AND CARBON; AND OF THE NITRATS AND CARBONATS.

Mrs. B. I AM almost afraid of introducing the subject of the NITRIC ACID, as I am sure that I shall be blamed by Caroline for not having made her acquainted with it before.

Caroline. Why so, Mrs. B.?

Mrs. B. Because you have long known its radical, which is nitrogen or azote; and in treating of that element, I did not even hint that it was the basis of an acid.

Caroline. And what could be your reason for not mentioning this acid sooner?

Mrs. B. I do not know whether you will think the reason sufficiently good to acquit me; but the omission, I assure you, did not proceed from negligence. You may recollect that nitrogen was one of the first simple bodies which we examined; you were then ignorant of the theory of combustion, which I believe was, for the first time, mentioned in that lesson; and therefore it would have been in vain, at that time, to have attempted to explain the nature and formation of acids.

Caroline. I wonder, however, that it never occurred to us to enquire whether nitrogen could be acidified; for, as we knew it was classed among the combustible bodies, it was natural to suppose that it might produce an acid.

Mrs. B. That is not a necessary consequence: for it might combine with oxygen only in the degree requisite to form an oxyd. But you will find that nitrogen is susceptible of various degrees of oxygenation, some of which convert it merely into an oxyd, and others give it all the acid properties.

The acids, resulting from the combination of oxygen and nitrogen, are called the NITROUS and NITRIC acids. We will begin with the NITRIC, in which nitrogen is in the highest state of oxygenation. This acid naturally exists in the form of gas; but is so very soluble in water, and has so great an affinity for it, that one grain of water will absorb and condense ten grains of acid gas, and form the limpid fluid which you see in this bottle.

Caroline. What a strong offensive smell it has!

Mrs. B. This acid contains a greater abundance of oxygen than any other, but it retains it with very little force.

Emily. Then it must be a powerful caustic, both from the facility with which it parts with its oxygen, and the quantity which it affords?

Mrs. B. Very well, Emily; both cause and effect are exactly such as you describe: nitric acid burns and destroys all kinds of organized matter. It even sets fire to some of the most combustible substances.—We shall pour a little of it over this piece of dry warm charcoal*—you see it inflames it immediately; it would do the same wlth oil of tupentine, phosphorus, and several other very combustible bodies. This shows you how easily this acid is decomposed by combustible bodies, since these effects must depend upon the absorption of its oxygen.

Nitric acid has been used in the arts from time immemorial, but it is only within these twenty-five years that its chemical nature has been ascertained. The celebrated Mr. Cavendish discovered that it consisted of about 10 parts of nitrogen and 25 of oxygen.† These principles, in the gaseous state, combine at a high temperature; and this may be effected by repeatedly passing the electrical spark through a mixture of the two gases.

Emily. The nitrogen and oxygen gases, of which the atmosphere is composed, do not combine, I suppose, because their temperature is not sufficiently elevated?

Caroline. But in a thunder-storm, when the lightning repeatedly passes through them, may it not produce nitric acid? We should be in a strange situation, if a violent storm should at once convert the atmosphere into nitric acid.

Mrs. B. There is no danger of it, my dear; the lightning can effect but a very small portion of the atmosphere, and though it were occasionally to produce a little nitric acid, yet this never could happen to such an extent as to be perceivable.

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* To inflame charcoal, a stronger acid than that sold at the shops is necessary. The experiment, with ol. turpentine and phosphorus, succeeds, if about a sixth part of sulph. acid is added to the nitric acid. The experiment with the turpentine requires caution. The vial containing the acid must be tied to a stick, a yard or two long, the operator pouring it into a small quantity of the turpentine standing at a distance. C.

† The proportion stated by Sir H. Davy, in his Chemical Researches, is as 1 to 2,389.

Emily. But how could the nitric acid be known, and used, before the method of combining its constituents was discovered?

Mrs. B. Before that period the nitric acid was obtained, and it is indeed still extracted, for the common purposes of art, from the compound salt which it forms with potash, commonly called *nitre*.

Caroline. Why is it so called? Pray, Mrs. B., let these old unmeaning names be entirely given up, by us at least; and let us call this salt *nitrat of potash*.

Mrs. B. With all my heart; but it is necessary that I should, at least, mention the old names, and more especially those which are yet in common use; otherwise, when you meet with them, you would not be able to understand their meaning.

Emily. And how is the acid obtained from this salt?

Mrs. B. By the intervention of sulphuric acid, which combines with the potash, and sets the nitric acid at liberty. This I can easily show you, by mixing some nitrat of potash and sulphuric acid in this retort, and heating it over a lamp; the nitric acid will come over in the form of vapour, which we shall collect in a glass bell. This acid, diluted in water, is commonly called *aqua fortis*, if Caroline will allow me to mention that name.

Caroline. I have often heard that aqua fortis will dissolve almost all metals; it is no doubt because it yields its oxygen so easily.

Mrs. B. Yes; and from this powerful solvent property, it derived the name of aqua fortis, or strong water. Do you not recollect that we oxydated, and afterwards dissolved, some copper in this acid?

Emily. If I remember right, the nitrat of copper was the first instance you gave us of a compound salt.

Caroline. Can the nitric acid be completely decomposed and converted into nitrogen and oxygen?

Emily. That cannot be the case, Caroline; since the acid can be decomposed only by the combination of its constituents with other bodies.

Mrs. B. True; but caloric is sufficient for this purpose. By making the acid pass through a red hot porcelain tube, it is decomposed; the nitrogen and oxygen regain the caloric which they had lost in combining, and are thus both restored to their gaseous state.

The nitric acid may also be partly decomposed, and is by this means converted into NITROUS ACID.

Caroline. This conversion must be easily effected, as the oxygen is so slightly combined with the nitrogen.

Mrs. B. The partial decomposition of nitric acid is readily effected by most metals; but it is sufficient to expose the nitric acid to a very strong light to make it give out oxygen gas, and thus be converted into nitrous acid. Of this acid there are various degrees, according to the proportions of oxygen which it contains; the strongest, and that into which the nitric is first converted, is of a yellow colour, as you see in this bottle.

Caroline. How it fumes when the stopper is taken out!

Mrs. B. The acid exists naturally in a gaseous state, and is here so strongly concentrated in water, that it is constantly escaping.

Here is another bottle of nitrous acid, which, you see, is of an orange red; this acid is weaker, the nitrogen being combined with a smaller quantity of oxygen; and with a still less proportion of oxygen it is an olive-green colour, as it appears in this third bottle. In short, the weaker the acid, the deeper is its colour.

Nitrous acid acts still more powerfully on some inflammable substances than the nitric.

Emily. I am surprised at that, as it contains less oxygen.

Mrs. B. But, on the other hand, it parts with its oxygen much more readily: you may recollect that we once inflamed oil with this acid.

The next combinations of nitrogen and oxygen form only oxyds of nitrogen, the first of which is commonly called *nitrous air;* or more properly *nitric oxyd gas.** This may be obtained from nitric acid, by exposing the latter to the action of metals, as in dissolving them it does not yield the whole of its oxygen, but retains a portion of this principle sufficient to convert it into this peculiar gas, a specimen of which I have prepared, and preserved within this inverted glass bell.

Emily. It is a perfectly invisible elastic fluid.

Mrs. B. Yes; and it may be kept any length of time in this manner over water, as it is not, like the nitric and nitrous acids, absorbable by it. It is rather heavier than atmospherical air, and is incapable of supporting either combustion or respiration.

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* To procure nitrous air put into a retort some filings, or shavings of copper, on which pour nitric acid, diluted with four or five parts of water; then apply the heat of a lamp, and receive the gas in the usual way, over water. C.

I am going to incline the glass gently on one side, so as to let some of the gas escape—

Emily. How very curious!—It produces orange fumes like the nitrous acid! that is the more extraordinary, as the gas within the glass is perfectly invisible.

Mrs. B. It would give me much pleasure if you could make out the reason of this curious change without requiring any further explanation.

Caroline. It seems, by the colour and smell, as if it were converted into nitrous acid gas; yet that cannot be, unless it combines with more oxygen; and how can it obtain oxygen the very instant it escapes from the glass?

Emily. From the atmosphere, no doubt. Is it not so, Mrs. B.?

Mrs. B. You have guessed it; as soon as it comes in contact with the atmosphere, it absorbs from it the additional quantity of oxygen necessary to convert it into nitrous acid gas. And, if I now remove the bottle entirely from the water, so as to bring at once the whole of the gas into contact with the atmosphere, this conversion will appear still more striking—

Emily. Look, Caroline, the whole capacity of the bottle is instantly tinged of an orange colour!

Mrs. B. Thus, you see, it is the most easy process imaginable to convert *nitrous oxyd gas* into *nitrous acid gas.* The property of attracting oxygen from the atmosphere, without any elevation of temperature, has occasioned this gaseous oxyd being used as a test for ascertaining the degree of purity of the atmosphere. I am going to show you how it is applied to this purpose.—You see this graduated glass tube, which is closed at one end, (Plate X. fig. 2.)—I first fill it with water, and then introduce a certain measure of nitrous gas, which, not being absorbable by water, passes through it, and occupies the upper part of the tube. I must now add rather above two-thirds of oxygen gas, which will just be sufficient to convert the nitrous oxyd gas into nitrous acid gas.

Caroline. So it has!—I saw it turn of an orange colour; but it immediately afterwards disappeared entirely, and the water, you see, has risen, and almost filled the tube.

Mrs. B. That is because the acid gas is absorbable by water, and in proportion as the gas impregnates the water, the latter rises in the tube. When the oxygen gas is very pure, and the required proportion of nitrous oxyd gas very exact, the whole is absorbed by the water; but if any other gas be mixed with the oxygen, instead of combining with the nitrous oxygen, it will remain and occupy the upper part of the tube; or if the gases be not in the due proportion, there will be a residue of that which predominates.—Before we leave this subject, I must not forget to remark that nitrous acid may be formed by dissolving nitrous oxyd gas in nitric acid. This solution may be effected simply by making bubbles of nitrous oxyd gas pass through nitric acid.

Emily. That is to say, that nitrogen at its highest degree of oxygenation, being mixed with nitrogen at its lowest degree of oxygenation, will produce a kind of intermediate substance, which is nitrous acid.

Mrs. B. You have stated the fact with great precision.—There are various other methods of preparing nitrous oxyd, and of obtaining it from compound bodies; but it is not necessary to enter into these particulars. It remains for me only to mention another curious modification of oxygenated nitrogen, which has been distinguished by the name of *gaseous oxyd of nitrogen*. It is but lately that this gas has been accurately examined, and its properties have been investigated chiefly by Sir H. Davy. It has obtained also the name of *exhilarating gas*, from the very singular property which that gentleman has discovered in it, of elevating the animal spirits, when inhaled into the lungs, to a degree sometimes resembling delirium or intoxication.

Caroline. Is it respirable, then?

Mrs. B. It can scarcely be called respirable, as it would not support life for any length of time; but it may be breathed for a few moments without any other effects, than the singular exhilaration of spirits I have just mentioned. It affects different people, however, in a very different manner. Some become violent, even outrageous; others experience a languor, attended with faintness; but most agree in opinion, that the sensations it excites are extremely pleasant.

Caroline. I think I should like to try it—how do you breathe it?

Mrs. B. By collecting the gas in a bladder, to which a short tube with a stop-cock is adapted; this is applied to the mouth with one hand, whilst the nostrils are kept closed with the other, that the common air may have no access. You then alternately inspire, and expire the gas, till you perceive its effects. But I cannot consent to your making the experiment; for the nerves are sometimes unpleasantly affected by it, and I would not run any risk of that kind.

Emily. I should like, at least, to see somebody breathe it; but pray by what means is this curious gas obtained?

Mrs. B. It is procured from *nitrat of ammonia*,* an artificial salt which yields this gas on the application of a gentle heat. I have put some of the salt into a retort, and by the aid of a lamp the gas will be extricated.

Caroline. Bubbles of air begin to escape through the neck of the retort into the water apparatus; will you not collect them?

Mrs. B. The gas that first comes over need not be preserved, as it consists of little more than the common air that was in the retort; besides, there is always in this experiment a quantity of watery vapour which must come away before the nitrous oxyd appears.

Emily. Watery vapour! Whence does that proceed? There is no water in nitrat of ammonia?

Mrs. B. You must recollect that there is in every salt a quantity of water of crystallisation, which may be evaporated by heat alone. But, besides this, water is actually generated in this experiment, as you will see presently. First tell me, what are the constituent parts of nitrat of ammonia?

Emily. Ammonia, and nitric acid; this salt, therefore, contains three different elements, nitrogen and hydrogen, which produce the ammonia; and oxygen, which, with nitrogen, forms the acid.

Mrs. B. Well then, in this process the ammonia is decomposed; the hydrogen quits the nitrogen to combine with some of the oxygen of the nitric acid, and forms with it the watery vapour which is now coming over. When that is effected, what will you expect to find?

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* To make nitrate of ammonia, take some nitric acid, or aquafortis—dilute it with four, or five parts of water; put it into a shallow earthen dish, and throw in pieces of carbonate of ammonia, until the effervescence ceases. Evaporate about one third of the liquor by a gentle heat, and set it away to crystallize. The crystals are long striated prisms. To procure the *nitrous oxide*, or *exhilarating* gas, and to try its effects by respiration, the following simple apparatus may be used, where a better is not at hand. Put some nitrate of ammonia into an oil flask, having first fitted to it a cork, and glass tube, bent so as to go under the receiver in the water bath. Then apply the gentle heat of a lamp.

For a receiver, fill a large jug with water, and invert it in the water bath: have fitted to the jug a cork, having two holes made through it with a burning iron; into one of these holes put a glass tube open at both ends, and nearly long enough to reach the bottom of the jug. Provide a large bladder furnished with a short tube tied to it. When the jug is nearly filled with the gas, remove, and set it upright by passing the hand under its mouth—then put in the cork and tube, the other opening in the cork being closed. When you wish to breathe the gas, take the stopper out of the cork, and pass in the tube attached to the bladder. Then by means of a small tunnel, pour water into the jug through the long tube, untill it drives out gas enough to fill the bladder. Mrs. B. describes the manner of breathing it.

Caution. Let the gas stand an hour or two over water before it is breathed. C.

Emily. Nitrous acid instead of nitric acid, and nitrogen instead of ammonia.

Mrs. B. Exactly so; and the nitrous acid and nitrogen combine, and form the gaseous oxyd of nitrogen, in which the proportion of oxygen is 37 parts to 63 of nitrogen.

You may have observed, that for a little while no bubbles of air have come over, and we have perceived only a stream of vapour condensing as it issued into the water.—Now bubbles of air again make their appearance, and I imagine that by this time all the watery vapour is come away, and that we may begin to collect the gas. We may try whether it is pure, by filling a phial with it, and plunging a taper into it—yes, it will do now, for the taper burns brighter than in the common air, and with a greenish flame.

Caroline. But how is that? I thought no gas would support combustion but oxygen or chlorine.

Mrs. B. Or any gas that contains oxygen, and is ready to yield it, which is the case with this in a considerable degree; it is not, therefore, surprising that it should accelerate the combustion of the taper.

You see that the gas is now produced in great abundance; we shall collect a large quantity of it, and I dare say that we shall find some of the family who will be curious to make the experiment of respiring it. Whilst this process is going on, we may take a general survey of the most important combinations of the nitric and nitrous acids with the alkalies.

The first of these is *nitrat of potash* commonly called *nitre* or *saltpetre.*

Caroline. Is not that the salt with which gunpowder is made?

Mrs B. Yes. Gunpowder is a mixture of five parts of nitre to one of sulphur, and one of charcoal.—Nitre, from its great proportion of oxygen, and from the facility with which it yields it, is the basis of most detonating compositions.

Emily. But what is the cause of the violent detonation of gunpowder when set fire to?

Mrs. B. Detonation may proceed from two causes; the sudden formation or destruction of an elastic fluid. In the first case, when either a solid or liquid is instantaneously converted into an elastic fluid, the prodigious and sudden expansion of the body strikes the air with great violence, and this concussion produces the sound called detonation.

Caroline. That I comprehend very well; but how can a similar effect be produced by the destruction of a gas?

Mrs. B. A gas can be destroyed only by condensing it to a liquid or solid state; when this takes place suddenly, the gas, in assuming a new and more compact form, produces a vacuum, into which the surrounding air rushes with great impetuosity; and it is by that rapid and violent motion that the sound is produced. In all detonations, therefore, gases are either suddenly formed, or destroyed. In that of gunpowder, can you tell me which of these two circumstances takes place?

Emily. As gunpowder is a solid, it must, of course, produce the gases in its detonation; but how, I cannot tell.

Mrs. B. The constituents of gunpowder, when heated to a certain degree, enter into a number of new combinations, and are instantaneously converted into a variety of gases, the sudden expansion of which gives rise to the detonation.

Caroline. And in what instance does the destruction or condensation of gases produce detonation?

Mrs. B. I can give you one with which you are well acquainted; the sudden combination of the oxygen and hydrogen gases.

Caroline. True; I recollect perfectly that hydrogen detonates with oxygen when the two gases are converted into water.

Mrs. B. But let us return to the nitrat of potash.—This salt is decomposed when exposed to heat, and mixed with any combustible body, such as carbon, sulphur, or metals, these substances oxydating rapidly at the expense of the nitrat. I must show you an instance of this.—I expose to the fire some of the salt in a small iron ladle, and, when it is sufficiently heated, add to it some powdered charcoal; this will attract the oxygen from the salt, and be converted into carbonic acid.—

Emily. But what occasions that crackling noise, and those vivid flashes that accompany it?

Mrs. B. The rapidity with which the carbonic acid gas is formed occasions a succession of small detonations, which, together with the emission of flame, is called *deflagration.*

Nitrat of ammonia we have already noticed, on account of the gaseous oxyd of nitrogen which is obtained from it.

Nitrat of silver is the lunar caustic, so remarkable for its property of destroying animal fibre, for which purpose it is often used by surgeons.—We have said so much on a former occasion, on the mode in which caustics act on animal matter, that I shall not detain you any longer on this subject.

We now come to the CARBONIC ACID, which we have already had many opportunities of noticing. You recollect that this acid may be formed by the combustion of carbon, whether in its imperfect state of charcoal, or in its purest form of diamond. And it is not necessary, for this purpose, to burn the carbon in oxygen gas, as we did in the preceding lecture; for you need only light a piece of charcoal and suspend it under a receiver on the water bath. The charcoal will soon be extinguished, and the air in the receiver will be found mixed with carbonic acid. The process, however, is much more expeditious if the combustion be performed in pure oxygen gas.

Caroline. But how can you separate the carbonic acid, obtained in this manner, from the air with which it is mixed?

Mrs. B. The readiest mode is to introduce under the receiver a quantity of caustic lime, or caustic alkali, which soon attracts the whole of the carbonic acid to form a carbonat.—The alkali is found increased in weight, and the volume of the air is diminished by a quantity equal to that of the carbonic acid which was mixed with it.

Emily. Pray is there no method of obtaining pure carbon from carbonic acid?

Mrs. B. For a long time it was supposed that carbonic acid was not decompoundable; but Mr. Tennant discovered, a few years ago, that this acid may be decomposed by burning phosphorus in a closed vessel with carbonat of soda or carbonat of lime: the phosphorus absorbs the oxygen from the carbonat, whilst the carbon is separated in the form of a black powder. This decomposition, however, is not effected simply by the attraction of the phosphorus for oxygen, since it is weaker than that of charcoal; but the attraction of the alkali or lime for the phosphoric acid, unites its power at the same time.

Caroline. Cannot we make that experiment?

Mrs. B. Not easily; it requires being performed with extreme nicety, in order to obtain any sensible quantity of carbon, and the experiment is much too delicate for me to attempt it. But there can be no doubt of the accuracy of Mr. Tennant's results; and all chemists now agree, that one hundred parts of carbonic acid gas consists of about twenty-eight parts of carbon, to seventy-two of oxygen gas. But if you recollect, we decomposed carbonic acid gas the other day by burning potassium in it.

Caroline. True, so we did; and found the carbon precipitated on the regenerated potash.

Mrs. B. Carbonic acid gas is found very abundantly in nature; it is supposed to form about one thousandth part of the atmosphere, and is constantly produced by the respiration of animals; it exists in a great variety of combinations, and is exhaled from many natural decompositions. It is contained in a state of great purity in certain caves, such as the *Grotto del Cane*, near Naples.

Emily. I recollect having read an account of that grotto, and of the cruel experiments made on the poor dogs, to gratify the curiosity of strangers. But I understood that the vapour exhaled by this cave was called *fixed air*.

Mrs. B. That is the name by which carbonic acid was known before its chemical composition was discovered.—This gas is more destructive of life than any other; and if the poor animals that are submitted to its effects are not plunged into cold water as soon as they become senseless, they do not recover. It extinguishes flame instantaneously. I have collected some in this glass, which I will pour over the candle.*

Caroline. This is extremely singular—it seems to extinguish the light as it were by enchantment, as the gas is invisible. I never should have imagined that gas could have been poured like a liquid.

Mrs. B. It can be done with carbonic acid only, as no other gas is sufficiently heavy to be susceptible of being poured out in the atmospherical air without mixing with it.

Emily. Pray by what means did you obtain this gas?

Mrs. B I procured it from marble. Carbonic acid gas has so strong an attraction for all the alkalies and alkaline earths, that these are always found in nature in the state of carbonate. Combined with lime, this acid forms chalk, which may be considered as the basis of all kinds of marbles, and calcareous stones. From these substances carbonic acid is easily separated, as it adheres so slightly to its combinations, that the carbonats are all decomposable by any of the other acids. I can easily show you how I obtained this gas; I poured some diluted sulphuric acid over pulverised marble in this bottle (the same which we used the other day to prepare hydrogen gas,) and the gas escaped through the tube connected with it; the operation still continues, as you may perceive—

Emily. Yes, it does; there is a great fermentation in the glass vessel. What singular commotion is excited by the sulphuric acid taking possession of the lime, and driving out the carbonic acid!

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* Merely pouring it over a candle, will not extinguish it. Put a short piece of candle, or taper, into the bottom of a deep tumbler, and then pour in the gas and the flame goes out as quickly as though you poured in water. C.

Caroline. But did the carbonic acid exist in a gaseous state in the marble?

Mrs. B. Certainly not; the acid, when in a state of combination, is capable of existing in a solid form.

Caroline. Whence, then, does it obtain the caloric necessary to convert it into gas?

Mrs. B. It may be supplied in this case from the mixture of sulphuric acid and water, which produces and evolution of heat, even greater than is required for the purpose; since, as you may perceive by touching the glass vessel, a considerable quantity of the caloric disengaged becomes sensible. But a supply of caloric may be obtained also from a diminution of capacity for heat, occasioned by the new combination which takes place; and, indeed, this must be the case when other acids are employed for the disengagement of carbonic acid gas, which do not, like the sulphuric, produce heat on being mixed with water. Carbonic acid may likewise be disengaged from its combinations by heat alone, which restores it to its gaseous state.

Caroline. It appears to me very extraordinary that the same gas, which is produced by the burning of wood and coals should exist also in such bodies as marble, and chalk, which are incombustible substances.

Mrs. B. I will not answer that objection, Caroline, because I think I can put you in a way of doing it yourself. Is carbonic acid combustible?

Caroline. Why, no—because it is a body which has been already burnt;* it is carbon only, and not the acid, that is combustible.

Mrs. B. Well, and what inference do you draw from this?

Caroline. That carbonic acid cannot render the bodies with which it is united combustible; but that simple carbon does, and that it is in this elementary state that it exists in wood, coals, and a great variety of other combustible bodies.—Indeed, Mrs. B., you are very ungenerous; you are not satisfied with convincing me that my objections are frivolous, but you oblige me to prove them so myself.

Mrs. B. You must confess, however, that I make ample amends for the detection of error, when I enable you to discover the truth. You understand, now, I hope, that carbonic acid is equally produced by the decomposition of chalk, or by the combustion of charcoal. These processes are certainly of a very different nature; in the first case the acid is already formed, and requires nothing more than heat to restore it to its gaseous state, whilst, in the latter, the acid is actually made by the process of combustion.

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* Not *burnt* in the common acceptation of the word. The carbon is already united to oxygen, and therefore has no affinity for it. In the artificial production of carbonic acid, the carbon is burnt. C.

Caroline. I understand it now perfectly. But I have just been thinking of another difficulty, which, I hope, you will excuse my not being able to remove myself. How does the immense quantity of calcareous earth, which is spread all over the globe, obtain the carbonic acid with which it is combined?

Mrs. B. The question is, indeed, not very easy to answer; but I conceive that the general carbonisation of calcareous matter may have been the effect of a general combustion,* occasioned by some revolution of our globe, and producing an immense supply of carbonic acid, with which the calcareous matter became impregnated; or that this may have been effected by a gradual absorption of carbonic acid from the atmosphere.—But this would lead us to discussions which we cannot indulge in, without deviating too much from our subject.

Emily. How does it happen that we do not perceive the pernicious effects of the carbonic acid which is floating in the atmosphere?

Mrs. B. Because of the state of very great dilution in which it exists there. But can you tell me, Emily, what are the sources which keep the atmosphere constantly supplied with this acid?

Emily. I suppose the combustion of wood, coals, and other substances, that contain carbon.

Mrs. B. And also the breath of animals.

Caroline. The breath of animals! I thought you said that this gas was not at all respirable, but on the contrary, extremely poisonous.

Mrs. B. So it is; but although animals cannot breathe in carbonic acid gas, yet, in the process of respiration, they have the power of forming this gas in their lungs; so that the air which we *expire*, or reject from the lungs, always contains a certain proportion of carbonic acid, which is much greater than that which is commonly found in the atmosphere.

Caroline. But what is it that renders carbonic acid such a deadly poison?

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* This idea is at random. We cannot account for the origin of carbonic acid in its native state any better than we can for oxygen. It cannot be the product of combustion, since it existed before the growth of combustible materials. C.

Mrs. B. The manner in which this gas destroys life, seems to be merely by preventing the access of respirable air; for carbonic acid gas, unless very much diluted with common air, does not penetrate into the lungs, as the windpipe actually contracts and refuses it admittance.—But we must dismiss this subject at present, as we shall have an opportunity of treating of respiration much more fully, when we come to the chemical functions of animals.

Emily. Is carbonic acid as destructive to the life of vegetables as it is to that of animals?

Mrs. B. If a vegetable be completely immersed in it, I believe it generally proves fatal to it; but mixed in certain proportions with atmospherical air, it is, on the contrary, very favourable to vegetation.

You remember, I suppose, our mentioning the mineral waters, both natural and artificial, which contain carbonic acid gas?

Caroline. You mean the Seltzer water?

Mrs. B. That is one of those which are the most used; there are, however, a variety of others into which carbonic acid enters as an ingredient: all these waters are usually distinguished by the name of *acidulous* or *gaseous mineral waters*.

The class of salts called *carbonats* is the most numerous in nature; we must pass over them in a very cursory manner, as the subject is far too extensive for us to enter on it in detail. The state of carbonat is the natural state of a vast number of minerals, and particularly of the alkalies and alkaline earths, as they have so great an attraction for the carbonic acid, that they are almost always found combined with it; and you may recollect that it is only by separating them from this acid, that they acquire that causticity and those striking qualities which I have formerly described. All marbles, chalks, shells, calcareous spars, and lime-stones of every description, are neutral salts, in which *lime*, their common basis, has lost all its characteristic properties.

Emily. But if all these various substances are formed by the union of lime with carbonic acid, whence arises their diversity of form and appearance?

Mrs. B. Both from the different proportions of their component parts, and from a variety of foreign ingredients which may be occasionally blended with them: the veins and colours of marbles, for instance, proceed from a mixture of metallic substances; silex and alumine also frequently enter into these combinations. The various carbonats, therefore, which I have enumerated, cannot be considered as pure unadulterated neutral salts, although they certainly belong to that class of bodies.

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CONVERSATION XIX.

ON THE BORACIC, FLUORIC, MURIATIC, AND OXYGENATED MURIATIC ACIDS; AND ON MURIATS.—ON IODINE AND IODIC ACID.

Mrs. B. We now come to the three remaining acids with simple bases, the compound nature of which, though long suspected, has been but recently proved. The chief of these is the muriatic; but I shall first describe the two others, as their bases have been obtained more distinctly than that of the muriatic acid.

You may recollect I mentioned the BORACIC ACID. This is found very sparingly in some parts of Europe, but for the use of manufactures we have always received it from the remote country of Thibet, where it is found in some lakes, combined with soda. It is easily separated from the soda by sulphuric acid, and appears in the form of shining scales, as you see here.

Caroline. I am glad to meet with an acid which we need not be afraid to touch; for I perceive, from your keeping it in a piece of paper, that it is more innocent than our late acquaintance, the sulphuric and nitric acids.

Mrs. B. Certainly; but being more inert, you will not find its properties so interesting. However its decomposition, and the brilliant spectacle it affords when its basis again unites with oxygen, atones for its want of other striking qualities.

Sir H. Davy succeeded in decomposing the boracic acid, (which had till then, been considered as undecompoundable,) by various methods. On exposing this acid to the Voltaic battery, the positive wire gave out oxygen, and on the negative wire was deposited a black substance, in appearance resembling charcoal. This was the basis of the acid, which Sir H. Davy has called *Boracium*, or *Boron*.

The same substance was obtained in more considerable quantities, by exposing the acid to a great heat in an iron gun-barrel.

A third method of decomposing the boracic acid consisted in burning potassium in contact with it in vacuo. The potassium attracts the oxygen from the acid, and leaves its basis in a separate state.

The recomposition of this acid I shall show you, by burning some of its basis, which you see here, in a retort full of oxygen gas. The heat of a candle is all that is required for this combustion.—

Emily. The light is astonishingly brilliant, and what beautiful sparks it throws out!

Mrs. B. The result of this combustion is the boracic acid, the nature of which, you see, is proved both by analytic and synthetic means. Its basis has not, it is true, a metallic appearance; but it makes very hard alloys with other metals.

Emily. But pray, Mrs. B., for what purpose is the boracic acid used in manufactures?

Mrs. B. Its principal use is in conjunction with soda, that is, in the state of *borat of soda*, which in the arts is commonly called borax. This salt has a peculiar power of dissolving metallic oxyds, and of promoting the fusion of substances capable of being melted; it is accordingly employed in various metallic arts; it is used, for example, to remove the oxyd from the surface of metals, and is often employed in the assaying of metallic ores.

Let us now proceed to the FLUORIC ACID. This acid is obtained from a substance which is found frequently in mines, and particularly in those of Derbyshire, called *fluor*, a name which it acquired from the circumstance of its being used to render the ores of metals more fluid when heated.

Caroline. Pray is not this the Derbyshire spar of which so many ornaments are made?

Mrs. B. The same; but though it has long been employed for a variety of purposes, its nature was unknown until Scheele, the great Swedish chemist, discovered that it consisted of lime united with a peculiar acid, which obtained the name of *fluoric acid.* It is easily separated from the lime by the sulphuric acid, and unless condensed in water, ascends in the form of gas. A very peculiar property of this acid is its union with siliceous earths, which I have already mentioned. If the distillation of this acid is performed in glass vessels, they are corroded, and the siliceous part of the glass comes over, united with the gas; if water is then admitted, part of the silex is deposited, as you may observe in this jar.

Caroline. I see white flakes forming on the surface of the water; is that silex?

Mrs. B. Yes it is. This power of corroding glass has been used for engraving, or rather etching, upon it. The glass is first covered with a coat of wax, through which the figures to be engraved are to be scratched with a pin; then pouring the fluoric acid over the wax, it corrodes the glass where the scratches have been made.

Caroline. I should like to have a bottle of this acid, to make engravings.*

Mrs. B. But you could not have it in a *glass* bottle, for in that case the acid would be saturated with silex, and incapable of executing an engraving; the same thing would happen were the acid kept in vessels of porcelain or earthen-ware; this acid must therefore be both prepared and preserved in vessels of silver.

If it be distilled from fluor spar and vitriolic acid, in silver or leaden vessels, the receiver being kept very cold during the distillation, it assumes the form of a dense fluid, and in that state is the most intensely corrosive substance known. This seems to be the acid combined with a little water. It may be called *hydro fluoric acid;* and Sir H. Davy has been led, from some late experiments on the subject, to consider *pure* fluoric acid as a compound of a certain unknown principle, which he calls *fluorine*, with hydrogen.

Sir H. Davy has also attempted to decompose the fluoric acid by burning potassium in contact with it; but he has not yet been able by this or any other method, to obtain its basis in a distinct separate state.

We shall conclude our account of the acids with that of the MURIATIC ACID, which is perhaps the most curious and interesting of all of them. It is found in nature combined with soda, lime, and magnesia. *Muriat of soda* is the common sea-salt, and from this substance the acid is usually disengaged by means of the sulphuric acid. The natural state of the muriatic acid is that of an invisible permanent gas, at the common temperature of the atmosphere; but it has a remarkably strong attraction for water, and assumes the form of a whitish cloud whenever it meets any moisture to combine with. This acid is remarkable for its peculiar and very pungent smell, and possesses, in a powerful degree, most of the acid properties. Here is a bottle containing muriatic acid in a liquid state.

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* A bottle of fluoric acid is not easily obtained. To make etchings on glass, first cover the glass with a thin coat of bees wax. This is done by warming it over a lamp, and passing the wax over the surface. Then make the drawing by cutting through the wax quite down to the glass. To do the etching in the small way, take a lead, or tin cup, and on the bottom, place about a table spoonful of pulverised fluor spar, and on this pour sulphuric acid enough to moisten it—place the glass on the cup as a cover, with the side to be etched downward—then set the cup in warm water, or warm the bottom over a lamp, taking care not to melt the wax. In 15 or 20 minutes or more, the etching will be done. In this way, drawings are easily and beautifully made on glass. C.

Caroline. And how is it liquefied ?

Mrs. B. By impregnating water with it; its strong attraction for water makes it very easy to obtain it in a liquid form. Now, if I open the phial, you may observe a kind of vapour rising from it, which is muriatic acid gas, of itself invisible, but made apparent by combining with the moisture of the atmosphere.

Emily. Have you not any of the pure muriatic acid gas ?

Mrs. B. This jar is full of that acid in its gaseous state—it is inverted over mercury instead of water, because, being absorbable by water, this gas cannot be confined by it.—I shall now raise the jar a little on one side, and suffer some of the gas to escape.—You see that it immediately becomes visible in the form of a cloud.

Emily. It must be, no doubt, from its uniting with the moisture of the atmosphere, that it is converted into this dewy vapour.

Mrs. B. Certainly; and for the same reason, that is to say, its extreme eagerness to unite with water, this gas will cause snow to melt as rapidly as an intense fire.

This acid proved much more refractory when Sir H. Davy attempted to decompose it, than the other two undecompounded acids. It is singular that potassium will burn in muriatic acid, and be converted into potash, without decomposing the acid, and the result of this combustion is a *muriat of potash;* for the potash, as soon as it is regenerated, combines with the muriatic acid.

Caroline. But how can the potash be regenerated, if the muriatic acid does not oxydate the potassium ?

Mrs. B. The potassium, in this process, obtains oxygen from the moisture with which the muriatic acid is always combined, and accordingly hydrogen, resulting from the decomposition of the moisture, is invariably evolved.

Emily. But why not make these experiments with dry muriatic acid ?

Mrs. B. Dry acids cannot be acted on by the Voltaic battery, because acids are non-conductors of electricity, unless moistened. In the course of a number of experiments which Sir H. Davy made upon acids in a state of dryness, he observed that the presence of water appeared always necessary to develope the acid properties, so that acids are not even capable of reddening vegetable blues if they have been carefully deprived of moisture. This remarkable circumstance led him to suspect, that water, instead of oxygen, may be the acidifying principle;

but this he threw out rather as a conjecture than as an established point.

Sir H. Davy obtained very curious results from burning potassium in a mixture of phosphorus and muriatic acid, and also of sulphur and muriatic acid; the latter detonates with great violence. All his experiments, however, failed in presenting to his view the basis of the muriatic acid, of which he was in search; and he was at last induced to form an opinion respecting the nature of this acid, which I shall presently explain.

Emily. Is this acid susceptible of different degrees of oxygenation?

Mrs. B. Yes, for though we cannot deoxygenate this acid, yet we may add oxygen to it.

Caroline. Why then, is not the least degree of oxygenation of the acid called the *muriatous*, and the higher degree the *muriatic* acid?

Mrs. B. Because, instead of becoming, like other acids, more dense, and more acid by an addition of oxygen, it is rendered on the contrary more volatile, more pungent, but less acid, and less absorbable by water. These circumstances, therefore, seem to indicate the propriety of making an exception to the nomenclature. The highest degree of oxygenation of this acid has been distinguished by the additional epithet of *oxygenated*, or, for the sake of brevity, *oxy*, so that it is called the *oxygenated*, or *oxy-muriatic acid*. This likewise exists in a gaseous form, at the temperature of the atmosphere; it is also susceptible of being absorbed by water, and can be congealed, or solidified, by a certain degree of cold.

Emily. And how do you obtain the oxy-muriatic acid?

Mrs. B. In various ways; but it may be most conveniently obtained by distilling liquid muriatic acid over oxyd of manganese, which supplies the acid with the additional oxygen. One part of the acid being put into a retort, with two parts of the oxyd of manganese, and the heat of a lamp applied, the gas is soon disengaged, and may be received over water, as it is but sparingly absorbed by it.—I have collected some in this jar—*

Caroline. It is not invisible, like the generality of gases; for it is of a yellowish colour.

Mrs. B. The muriatic acid extinguishes flame, whilst, on the contrary, the oxymuriatic makes the flame larger, and gives it a dark red colour. Can you account for this difference in the two acids?

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* Breathing only a few bubbles of this gas is attended with bad,—sometimes with dangerous consequences. The young chemist, therefore had better not undertake to make it. C.

Emily. Yes, I think so; the muriatic acid will not supply the flame with the oxygen necessary for its support; but when this acid is further oxygenated, it will part with its additional quantity of oxygen, and in this way support combustion.

Mrs. B. That is exactly the case; indeed the oxygen added to the muriatic acid adheres so slightly to it, that it is separated by mere exposure to the sun's rays. This acid is decomposed also by combustible bodies, many of which it burns, and actually inflames, without any previous increase of temperature.

Caroline. That is extraordinary, indeed! I hope you mean to indulge us with some of these experiments?

Mrs. B. I have prepared several glass jars of oxy-muriatic acid gas for that purpose. In the first we shall introduce some Dutch gold leaf.—Do you observe that it takes fire?

Emily. Yes, indeed it does—how wonderful it is! It became immediately red hot, but was soon smothered in a thick vapour.

Caroline. What a disagreeable smell!

Mrs. B. We shall try the same experiment with phosphorus in another jar of this acid.—You had better keep your handkerchief to your nose when I open it—now let us drop into it this little piece of phosphorus—

Caroline. It burns really; and almost as brilliantly as in oxygen gas! But, what is most extraordinary, these combustions take place without the metal or phosphorus being previously lighted, or even in the least heated.

Mrs. B. All these curious effects are owing to the very great facility with which this acid yields oxygen to such bodies as are strongly disposed to combine with it. It appears extraordinary indeed to see bodies, and metals in particular, melted down and inflamed, by a gas without any increase of temperature, either of the gas, or of the combustible. The phenomenon, however, is, you see, well accounted for.

Emily. Why did you burn a piece of Dutch gold leaf rather than a piece of any other metal?

Mrs. B. Because, in the first place, it is a composition of metals (consisting chiefly of copper) which burns readily; and I use a thin metallic leaf in preference to a lump of metal, because it offers to the action of the gas but a small quantity of matter under a large surface. Filings, or shavings, would answer the purpose nearly as well; but a lump of metal, though the surface would oxydate with great rapidity, would not take fire. Pure gold is not inflamed by oxy-muriatic acid gas, but it is rapidly oxydated, and dissolved by it; indeed, this acid is the only one that will dissolve gold.

Emily. This, I suppose, is what is commonly called *aqua* *regia*, which you know is the only thing that will act upon gold.

Mrs. B. That is not exactly the case either; for aqua regia is composed of a mixture of muriatic acid and nitric acid.—But in fact, the result of this mixture is the formation of oxy-muriatic acid, as the muriatic acid oxygenates itself at the expense of the nitric; this mixture, therefore, though it bears the name of *nitro-muriatic acid*, acts on gold merely in virtue of the oxy-muriatic acid which it contains.

Sulphur, volatile oils, and many other substances, will burn in the same manner in oxy-muriatic acid gas; but I have not prepared a sufficient quantity of it, to show you the combustion of all these bodies.

Caroline. There are several jars of the gas yet remaining.

Mrs. B. We must reserve these for future experiments. The oxy-muriatic acid, does not, like other acids, redden the blue vegetable colours; but it totally destroys all colour, and turns vegetables perfectly white. Let us collect some vegetable substances to put into this glass, which is full of gas.

Emily. Here is a sprig of myrtle—

Caroline. And here some coloured paper—

Mrs. B. We shall also put in this piece of scarlet riband, and a rose—

Emily. Their colours begin to fade immediately! But how does the gas produce this effect?

Mrs. B. The oxygen combines with the colouring matter of these substances, and destroys it; that is to say, destroys the property which these colours had of reflecting only one kind of rays, and renders them capable of reflecting them all, which, you know, will make them appear white. Old prints may be cleansed by this acid, for the paper will be whitened without injury to the impression, as printer's ink is made of materials (oil and lamp black) which are not acted upon by acids.

This property of the oxy-muriatic acid has lately been employed in manufactures in a variety of bleaching processes; but for these purposes the gas must be dissolved in water, as the acid is thus rendered much milder and less powerful in its effects; for, in a gaseous state, it would destroy the texture, as well as the colour of the substance submitted to its action.

Caroline. Look at the things which we put into the gas; they have now entirely lost their colour!

Mrs. B. The effect of the acid is almost completed; and if we were to examine the quantity that remains, we should find it to consist chiefly of muriatic acid.

The oxy-muriatic acid has been used to purify the air in fever hospitals and prisons, as it burns and destroys putrid effluvia of every kind. The infection of the small-pox is likewise destroyed by this gas, and matter that has been submitted to its influence will no longer generate that disorder.

Caroline. Indeed, I think the remedy must be nearly as bad as the disease; the oxy-muriatic acid has such a dreadfully suffocating smell.

Mrs. B. It is certainly extremely offensive: but by keeping the mouth shut, and wetting the nostrils with liquid ammonia, in order to neutralise the vapour as it reaches the nose, its prejudicial effects may be in some degree prevented. At any rate, however, this mode of disinfection can hardly be used in places that are inhabited. And as the vapour of nitric acid, which is scarcely less efficacious for this purpose, is not at all prejudicial, it is usually preferred on such occasions.

Caroline. You have not told us yet what is Sir H. Davy's new opinion respecting the nature of muriatic acid, to which you alluded a few minutes ago?

Mrs. B. True; I avoided noticing it then, because you could not have understood it without some previous knowledge of the oxy-muriatic acid, which I have but just introduced to your acquaintance.

Sir H. Davy's idea is that muriatic acid, instead of being a compound, consisting of an unknown basis and oxygen, is formed by the union of oxy-muriatic gas with hydrogen?

Emily. Have you not told us just now that oxy-muriatic gas was itself a compound of muriatic acid and oxygen?

Mrs. B. Yes; but according to Sir H. Davy's hypothesis, oxy-muriatic gas is considered as a simple body, which contains no oxygen—as a substance of its own kind, which has a great analogy to oxygen in most of its properties, though in others it differs entirely from it.—According to this view of the subject, the name of *oxy-muriatic acid* can no longer be proper, and therefore Sir H. Davy has adopted that of *chlorine*, or *chlorine gas*, a name which is simply expressive of its greenish colour; and in compliance with that philosopher's theory, we have placed chlorine in our table among the simple bodies.

Caroline. But what was Sir H. Davy's reason for adopting an opinion so contrary to that which had hitherto prevailed?

Mrs. B. There are many circumstances which are favourable to the new doctrine; but the clearest and simplest fact in its support is, that if hydrogen gas and oxy-muriatic gas be mixed together, both these gases disappear, and muriatic acid gas is formed.

Emily. That seems to be a complete proof; is it not considered as perfectly conclusive?

Mrs. B. Not so decisive as it appears at first sight; because it is argued by those who still incline to the old doctrine, that muriatic acid gas, however dry it may be, always contains a certain quantity of water, which is supposed essential to its formation. So that, in the experiment just mentioned, this water is supplied by the union of the hydrogen gas with the oxygen of the oxy-muriatic acid; and therefore the mixture resolves itself into the base of muriatic acid and water, that is, muriatic acid gas.

Caroline. I think the old theory must be the true one; for otherwise how could you explain the formation of oxy-muriatic gas, from a mixture of muriatic acid and oxyd of manganese?

Mrs. B. Very easily; you need only suppose that in this process the muriatic acid is decomposed; its hydrogen unites with the oxygen of the manganese to form water, and the chlorine appears in its separate state.

Emily. But how can you explain the various combustions which take place in oxy-muriatic gas, if you consider it as containing no oxygen?

Mrs. B. We need only suppose that combustion is the result of intense chemical action;* so that chlorine, like oxygen, in combining with bodies, forms compounds which have less capacity for caloric than their constituent principles, and, therefore, caloric is evolved at the moment of their combination.

Emily. If, then, we may explain every thing by either theory, to which of the two shall we give the preference?

Mrs. B. It will, perhaps, be better to wait for more positive proofs, if such can be obtained, before we decide positively upon the subject. The new doctrine has certainly gained ground very rapidly, and may be considered as nearly established; but several competent judges still refuse their assent to it, and until that theory is very generally adopted, it may be as well for us still occasionally to use the language to which chemists have long been accustomed.—But let us proceed to the examination of salts formed by muriatic acid.

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* "Intense chemical action," neither explains the process, nor indeed conveys to the mind any definite idea. The views of Sir H. Davy on the composition of chlorine, are combatted by many of the first chemists in England, as well as in this country. The inquisitive reader may become acquainted with the grounds of dispute on both sides by referring to Cooper's edition of Thomson's chemistry. C.

Among the compound salts formed by muriatic acid, the *muriat of soda*, or common salt, is the most interesting.* The uses and properties of this salt are too well known to require much comment. Besides the pleasant flavour it imparts to the food, it is very wholesome, when not used to excess, as it assists the process of digestion.

Sea-water is the great source from which muriat of soda is extracted by evaporation. But it is also found in large solid masses in the bowels of the earth, in England, and in many other parts of the world.

Emily. I thought that salts, when solid, were always in the state of crystals; but the common table-salt is in the form of a coarse white powder.

Mrs. B. Crystallisation depends, as you may recollect, on the slow and regular reunion of particles dissolved in a fluid; common sea-salt is only in a state of imperfect crystallisation, because the process by which it is prepared is not favourable to the formation of regular crystals. But if you dissolve it, and afterwards evaporate the water slowly, you will obtain a regular crystallisation.

Muriat of ammonia is another combination of this acid, which we have already mentioned as the principal source from which ammonia is derived.

I can at once show you the formation of this salt by the immediate combination of muriatic acid with ammonia.—These two glass jars contain, the one muriatic acid gas, the other ammoniacal gas, both of which are perfectly invisible—now, if I mix them together, you see they immediately form an opaque white cloud, like smoke.—If a thermometer was placed in tha jar in which these gases are mixed, you would perceive that some heat is at the same time produced.

Emily. The effects of chemical combinations, are, indeed, wonderful!—How extraordinary it is that two invisible bodies should become visible by their union!

Mrs. B. This strikes you with astonishment, because it is a phenomena which nature seldom exhibits to our view; but the most common of her operations are as wonderful, and it is their frequency only that prevents our regarding them with equal admiration. What would be more surprising, for instance, than combustion, were it not rendered so familiar by custom?

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* According to Sir H. Davy's views of the nature of the muriatic and oxy-muriatic acids, dry muriat of soda is a compound of sodium and chlorine, for it may be formed by the direct combination of oxy-muriatic gas and sodium. In his opinion, therefore, what we commonly call muriat of soda contains neither soda nor muriatic acid.

Emily. That is true.—But pray, Mrs. B., is this white cloud the salt that produces ammonia? How different it is from the solid muriat of ammonia which you once showed us!

Mrs. B. It is the same substance which first appears in the state of vapour, but will soon be condensed by cooling against the sides of the jar, in the form of very minute crystals.

We may now proceed to the *oxy-muriats.* In this class of salts the *oxy-muriat of potash*[*] is the most worthy of our attention, for its striking properties. The acid, in this state of combination, contains a still greater proportion of oxygen than when alone.

Caroline. But how can the oxy-muriatic acid acquire an increase of oxygen by combining with potash?

Mrs. B. It does not really acquire an additional quantity of oxygen, but it loses some of the muriatic acid, which produces the same effect, as the acid which remains is proportionably super-oxygenated.[†]

If this salt be mixed, and merely rubbed together with sulphur, phosphorus, charcoal, or indeed any other combustible, it explodes strongly.

Caroline. Like gun-powder, I suppose, it is suddenly converted into elastic fluids?

Mrs. B. Yes; but with this remarkable difference, that no increase of temperature, any further than is produced by gentle friction, is required in this instance. Can you tell me what gases are generated by the detonation of this salt with charcoal?

Emily. Let me consider . . . . . The oxy-muriatic acid parts with its excess of oxygen to the charcoal, by which means it is converted into muriatic acid gas; whilst the charcoal, being burnt by the oxygen, is changed to carbonic acid gas—What becomes of the potash I cannot tell.

Mrs. B. That is a fixed product which remains in the vessel.

Caroline. But since the potash does not enter into the new combinations, I do not understand of what use it is in this operation. Would not the oxy-muriatic acid and the charcoal produce the same effect without it?

Mrs. B. No; because there would not be that very great concentration of oxygen which the combination with the potash produces, as I have just explained.

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[*] Oxy-muriat of potash is prepared by passing chlorine through a solution of potash in water. The process is long and difficult. C.

[†] According to Sir H. Davy's new views, just explained, oxy-muriat of potash is a compound of chlorine with oxyd of potassium.

I mean to show you this experiment, but I would advise you not to repeat it alone; for if care be not taken to mix only very small quantities at a time, the detonation will be extremely violent, and may be attended with dangerous effects. You see I mix an exceedingly small quantity of the salt with a little powdered charcoal, in this Wedgwood mortar, and rub them together with the pestle—

Caroline. Heavens! How can such a loud explosion be produced by so small a quantity of matter?

Mrs. B. You must consider that an extremely small quantity of solid substance may produce a very great volume of gases; and it is the sudden evolution of these which occasions the sound.

Emily. Would not oxy-muriat of potash make a stronger gun-powder than nitrat of potash?

Mrs. B. Yes; but the preparation, as well as the use of this salt, is attended with so much danger, that it is never employed for that purpose.

Caroline. There is no cause to regret it, I think; for the common gun-powder is quite sufficiently destructive.

Mrs. B. I can show you a very curious experiment with this salt; but it must again be on condition that you will never attempt to repeat it by yourselves. I throw a small piece of phosphorus into this glass of water; then a little oxy-muriat of potash; and, lastly, I pour in (by means of this funnel, so as to bring it in contact with the two other ingredients at the bottom of the glass) a small quantity of sulphuric acid—

Caroline. This is, indeed, a beautiful experiment! The phosphorus takes fire and burns from the bottom of the water.

Emily. How wonderful it is to see flame bursting out under water, and rising through it! Pray, how is this accounted for?

Mrs. B. Cannot you find it out, Caroline?

Emily. Stop—I think I can explain it. Is it not because the sulphuric acid decomposes the salt by combining with the potash, so as to liberate the oxymuriatic acid gas by which the phosphorus is set on fire?

Mrs. B. Very well, Emily; and with a little more reflection you would have discovered another concurring circumstance, which is, that an increase of temperature is produced by the mixture of the sulphuric acid and water, which assists in promoting the combustion of the phosphorus.

I must, before we part, introduce to your acquaintance the newly-discovered substance IODINE, which you may recollect we placed next to oxygen and chlorine in our table of simple bodies.

Caroline. Is this also a body capable of maintaining combustion like oxygen and chlorine?

Mrs. B. It is; and although it does not so generally disengage light and heat from inflammable bodies, as oxygen and chlorine do, yet it is capable of combining with most of them; and sometimes, as in the instance of potassium and phosphorus, the combination is attended with an actual appearance of light and heat.

Caroline. But what sort of a substance is iodine: what is its form, and colour?

Mrs. B. It is a very singular body, in many respects. At the ordinary temperature of the atmosphere, it commonly appears in the form of blueish black crystalline scales, such as you see in this tube.

Caroline. They shine like black lead, and some of the scales have the shape of lozenges.

Mrs. B. That is actually the form which the crystals of iodine often assumes. But if we heat them gently, by holding the tube over the flame of a candle, see what a change takes place in them.

Caroline. How curious! They seem to melt, and the tube immediately fills with a beautiful violet vapour. But look, Mrs. B., the same scales are now appearing at the other end of the tube.

Mrs. B. This is in fact a sublimation of iodine, from one part of the tube to another; but with this remarkable peculiarity, that, while in the gaseous state, iodine assumes that bright violet colour, which, as you may already perceive, it loses as the tube cools, and the substance resumes its usual solid form. —It is from the violet colour of the gas that iodine has obtained its name.

Caroline. But how is this curious substance obtained?

Mrs. B. It is found in the ley of ashes of sea-weeds, after the soda has been separated by crystallisation; and it is disengaged by means of sulphuric acid, which expels it from the alkaline ley in the form of a violet gas, which may be collected and condensed in the way you have just seen.—This interesting discovery was made in the year 1812, by M. Courtois, a manufacturer of saltpetre at Paris.

Caroline. And pray, Mrs. B., what is the proof of iodine being a simple body?

Mrs. B. It is considered as a simple body, both because it is not capable of being resolved into other ingredients; and because it is itself capable of combining with other bodies, in a manner analogous to oxygen and chlorine. The most curious of these combinations is that which it forms with hydrogen gas, the result of which is a peculiar gaseous acid.

Caroline. Just as chlorine and hydrogen gas form muriatic acid? In this respect chlorine and iodine seem to bear a strong analogy to each other.

Mrs. B. That is indeed the case; so that if the theory of the constitution of either of these two bodies be true, it must be true also in regard to the other; if erroneous in the one, the theory must fall in both.

But it is now time to conclude; we have examined such of the acids and salts as I conceived would appear to you most interesting.—I shall not enter into any particulars respecting the metallic acids, as they offer nothing sufficiently striking for our present purpose.

CONVERSATION XX.

ON THE NATURE AND COMPOSITION OF VEGETABLES.

Mrs. B. We have hitherto treated only of the simplest combinations of elements, such as alkalies, earths, acids, compound salts, stones, &c.; all of which belong to the mineral kingdom. It is time now to turn our attention to a more complicated class of compounds, that of ORGANISED BODIES, which will furnish us with a new source of instruction and amusement.

Emily. By organised bodies, I suppose, you mean the vegetable and animal creation? I have, however, but a very vague idea of the word *organisation*, and I have often wished to know more precisely what it means.

Mrs. B. Organised bodies are such as are endowed by nature with various parts, peculiarly constructed and adapted to perform certain functions connected with life. Thus you may observe, that mineral compounds are formed by the simple effect of mechanical or chemical attraction, and may appear to some to be in a great measure the productions of chance; whilst organised bodies bear the most striking and impressive marks of design, and are eminently distinguished by that unknown principle, called *life*, from which the various organs derive the power of exercising their respective functions.

Caroline. But in what manner does life enable these organs to perform their several functions?

Mrs. B. That is a mystery, which, I fear, is enveloped in such profound darkness that there is very little hope of our ever being able to unfold it. We must content ourselves with examining the effects of this principle; as for the cause, we have been able only to give it a name, without attaching any other meaning to it than the vague and unsatisfactory idea of an unknown agent.

Caroline. And yet I think I can form a very clear idea of life.

Mrs. B. Pray let me hear how you would define it?

Caroline. It is perhaps more easy to conceive than to express—let me consider—Is not life the power which enables both the animal and the vegetable creation to perform the various functions which nature has assigned to them?

Mrs. B. I have nothing to object to your definition; but you will allow me to observe, that you have only mentioned the effects which the unknown cause produces, without giving us any notion of the cause itself.

Emily. Yes, Caroline, you have told us what life *does*, but you have not told us what it *is*.

Mrs. B. We may study its operations, but we should puzzle ourselves to no purpose by attempting to form an idea of its real nature.

We shall begin with examining its effects in the vegetable world, which constitutes the simplest class of organised bodies; these we shall find distinguished from the mineral creation, not only by their more complicated nature, but by the power which they possess within themselves, of forming new chemical arrangements of their constituent parts, by means of appropriate organs. Thus, though all vegetables are ultimately composed of hydrogen, carbon, and oxygen, (with a few other occasional ingredients,) they separate and combine these principles by their various organs, in a thousand ways, and form, with them, different kinds of juices and solid parts, which exist ready made in vegetables, and may, therefore, be considered as their immediate materials.

These are:

Sap,
Mucilage,
Sugar,
Fecula,
Gluten,
Fixed Oil,
Volatile Oil,
Camphor,
Resins,
Gum Resins,
Balsams,
Caoutchouc,
Extractive colouring Matter,
Tannin,
Woody Fibre,
Vegetable Acids, &c.

Caroline. What a long list of names! I did not suppose that a vegetable was composed of half so many ingredients.

Mrs. B. You must not imagine that every one of these materials is formed in each individual plant. I only mean to say, that they are all derived exclusively from the vegetable kingdom.

Emily. But does each particular part of the plant, such as the root, the bark, the stem, the seeds, the leaves, consist of one or these ingredients only, or of several of them combined together?

Mrs. B. I believe there is no part of a plant which can be said to consist solely of any one particular ingredient; a certain number of vegetable materials must always be combined for the formation of any particular part, (of a seed for instance,) and these combinations are carried on by sets of vessels, or minute organs, which select from other parts, and bring together, the several principles required for the developement and growth of those particular parts which they are intended to form and to maintain.

Emily. And are not these combinations always regulated by the laws of chemical attraction?

Mrs. B. No doubt; the organs of plants cannot force principles to combine that have no attraction for each other; nor can they compel superior attractions to yield to those of inferior power; they probably act rather mechanically, by bringing into contact such principles, and in such proportions, as will, by their chemical combination, form the various vegetable products.

Caroline. We may then consider each of these organs as a curiously constructed apparatus, adapted for the performance of a variety of chemical processes.

Mrs. B. Exactly so. As long as the plant lives and thrives, the carbon, hydrogen, and oxygen, (the chief constituents of its immediate materials,) are so balanced and connected together, that they are not susceptible of entering into other combinations; but no sooner does death take place, than this state of equilibrium is destroyed, and new combinations produced.

Emily. But why should death destroy it; for these principles must remain in the same proportions, and consequently, I should suppose, in the same order of attractions?

Mrs. B. You must remember, that in the vegetable, as well as in the animal kingdom, it is by the principle of *life* that the organs are enabled to act; when deprived of that agent or stimulus, their power ceases, and an order of attractions succeeds similar to that which would take place in mineral or unorganised matter.

Emily. It is this new order of attractions, I suppose, that destroys the organisation of the plant after death; for if the same combinations still continued to prevail, the plant would always remain in the state in which it died?

Mrs. B. And that, you know, is never the case; plants may be partially preserved for some time after death, by drying; but in the natural course of events they all return to the state of simple elements; a wise and admirable dispensation of Providence, by which dead plants are rendered fit to enrich the soil, and become subservient to the nourishment of living vegetables.

Caroline. But we are talking of the dissolution of plants, before we have examined them in their living state.

Mrs. B. That is true, my dear. But I wished to give you a general idea of the nature of vegetation, before we entered into particulars. Besides, it is not so irrelevant as you suppose to talk of vegetables in their dead state, since we cannot analyze them without destroying life; and it is only by hastening to submit them to examination, immediately after they have ceased to live, that we can anticipate their natural decomposition. There are two kinds of analysis of which vegetables are susceptible; first, that which separates them into their immediate materials, such as sap, resin, mucilage, &c.; secondly, that which decomposes them into their primitive elements, as carbon, hydrogen, and oxygen.

Emily. Is there not a third kind of analysis of plants, which consists in separating their various parts, as the stem, the leaves, and the several organs of the flower?

Mrs. B. That, my dear, is rather the department of the botanist; we shall consider these different parts of plants only, as the organs by which the various secretions or separations are performed; but we must first examine the nature of these secretions.

The *sap* is the principal material of vegetables, since it contains the ingredients that nourish every part of the plant. The basis of this juice, which the roots suck up from the soil, is water; this holds in solution the various other ingredients required by the several parts of the plant, which are gradually secreted from the sap by the different organs appropriated to that purpose, as it passes them in circulating through the plant.

Mucus, or *mucilage*, is a vegetable substance, which, like all the others, is secreted from the sap; when in excess, it exudes from trees in the form of gum.

Caroline. Is that the gum so frequently used instead of paste or glue?

Mrs B. It is; almost all fruit-trees yield some sort of gum, but that most commonly used in the arts is obtained from a species of acacia-tree in Arabia, and is called *gum arabic*; it forms the chief nourishment of the natives of those parts, who obtain it in great quantities from incisions which they make in the trees.

Caroline. I did not know that gum was eatable.

Mrs. B. There is an account of a whole ship's company being saved from starving by feeding on the cargo, which was gum senegal. I should not, however, imagine, that it would be either a pleasant or a particularly eligible diet to those who have not, from their birth, been accustomed to it. It is, however, frequently taken medicinally, and considered as very nourishing. Several kinds of vegetable acids may be obtained, by particular processes, from gum or mucilage, the principal of which is called the *mucous acid.*

Sugar is not found in its simple state in plants, but is always mixed with gum, sap, or other ingredients; this saccharine matter is to be met with in every vegetable, but abounds most in roots, fruits, and particularly in the sugar-cane.

Emily. If all vegetables contain sugar, why is it extracted exclusively from the sugar-cane?

Mrs. B. Because it is both most abundant in that plant, and most easily obtained from it. Besides, the sugars produced by other vegetables differ a little in their nature.

During the late troubles in the West-Indies, when Europe was but imperfectly supplied with sugar, several attempts were made to extract it from other vegetables, and very good sugar was obtained from parsnips and from carrots; but the process was too expensive to carry this enterprise to any extent.

Caroline. I should think that sugar might be more easily obtained from sweet fruits, such as figs, dates, &c.

Mrs. B. Probably; but it would be still more expensive, from the high price of those fruits.

Emily. Pray, in what manner is sugar obtained from the sugar-cane?

Mrs. B. The juice of this plant is first expressed by passing it between two cylinders of iron. It is then boiled with lime-water, which makes a thick scum rise to the surface. The clarified liquor is let off below and evaporated to a very small quantity, after which it is suffered to crystallize by standing in a vessel, the bottom of which is perforated with holes, that are imperfectly stopped, in order that the syrup may drain off.

The sugar obtained by this process is a coarse brown powder, commonly called raw or moist sugar; it undergoes another operation to be refined and converted into loaf sugar. For this purpose it is dissolved in water, and afterwards purified by an animal fluid called albumen. White of eggs chiefly consist of this fluid, which is also one of the constituent parts of blood; and consequently eggs, or bullocks' blood, are commonly used for this purpose.

The albuminous fluid being diffused through the syrup, combines with all the solid impurities contained in it, and rises with them to the surface, where it forms a thick scum; the clear liquor is then again evaporated to a proper consistence, and poured into moulds, in which, by a confused crystallisation, it forms loaf-sugar. But an additional process is required to whiten it; to this effect the mould is inverted, and its open base is covered with clay, through which water is made to pass; the water slowly trickling through the sugar, combines with and carries off the colouring matter.

Caroline. I am very glad to hear that the blood that is used to purify sugar does not remain in it; it would be a disgusting idea. I have heard of some improvements by the late Mr. Howard, in the process of refining sugar. Pray what are they?

Mrs. B. It would be much too long to give you an account of the process in detail. But the principal improvement relates to the mode of evaporating the syrup, in order to bring it to the consistency of sugar. Instead of boiling the syrup in a large copper, over a strong fire, Mr. Howard carries off the water by means of a large air-pump, in a way similar to that used in Mr. Leslie's experiment for freezing water by evaporation; that is, the syrup being exposed to a vacuum, the water evaporates quickly, with no greater heat than that of a little steam, which is introduced round the boiler. The air-pump is of course of large dimensions, and is worked by a steam engine. A great saving is thus obtained, and a striking instance afforded of the power of science in suggesting useful economical improvements.

Emily. And pray how is sugar-candy and barley-sugar prepared?

Mrs. B. Candied sugar is nothing more than the regular crystals, obtained by slow evaporation from a solution of sugar. Barley-sugar is sugar melted by heat, and afterwards cooled in moulds of a spiral form.

Sugar may be decomposed by a red heat, and, like all other vegetable substances, resolved into carbonic acid and hydrogen. The formation and the decomposition of sugar afford many very interesting particulars, which we shall fully examine, after having gone through the other materials of vegetables. We shall find that there is reason to suppose that sugar is not, like the other materials, secreted from the sap by appropriate organs; but that it is formed by a peculiar process with which you are not yet acquainted.

Caroline. Pray, is not honey of the same nature as sugar?

Mrs. B. Honey is a mixture of saccharine matter and gum.

Emily. I thought that honey was in some measure an animal substance, as it is prepared by the bees.

Mrs. B. It is rather collected by them from flowers, and conveyed to their store-houses, the hives. It is the wax only that undergoes a real alteration in the body of the bee, and is thence converted into an animal substance.*

Manna is another kind of sugar, which is united with a nauseous extractive matter, to which it owes its peculiar taste and colour. It exudes like gum from various trees in hot climates, some of which have their leaves glazed by it.

The next of the vegetable materials is *fecula*; this is the general name given to the farinaceous substance contained in all seeds, and in some roots, as the potatoe, parsnip, &c. It is intended by nature for the first aliment of the young vegetable; but that of one particular grain is become a favourite and most common food of a large part of mankind.

Emily. You allude, I suppose, to bread, which is made of wheat-flour?

Mrs. B. Yes. The fecula of wheat contains also another vegetable substance which seems peculiar to that seed, or at least has not as yet been obtained from any other. This is *gluten*, which is of a sticky, ropy, elastic nature; and it is supposed to be owing to the viscous qualities of this substance, that wheat-flour forms a much better paste than any other.

Emily. Gluten, by your description, must be very like gum?

Mrs. B. In their sticky nature they certainly have some resemblance; but gluten is essentially different from gum in other points, and especially in its being insoluble in water, whilst gum, you know, is extremely soluble.

The *oils* contained in vegetables all consist of hydrogen and carbon in various proportions. They are of two kinds, *fixed* and *volatile*, both of which we formerly mentioned. Do you remember in what the difference between fixed and volatile oil consists?

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* It was the opinion of Huber, that the bees prepared the wax from honey and sugar. There is, however, found on the leaves of some plants a substance, having all the properties of wax; and that bees-wax itself is not an animal substance, is clear from its analysis. C.

Emily. If I recollect rightly, the former are decomposed by heat, whilst the latter are merely volatilised by it.

Mrs. B. Very well. Fixed oil is contained only in the seeds of plants, excepting in the olive, in which it is produced in, and expressed from, the fruit. We have already observed that seeds contain also fecula; these two substances, united with a little mucilage, form the white substance contained in the seeds or kernels of plants, and is destined for the nourishment of the young plant, to which the seed gives birth. The milk of almonds, which is expressed from the seed of that name, is composed of these three substances.

Emily. Pray, of what nature is the linseed oil which is used in painting?

Mrs. B. It is a fixed oil, obtained from the seed of flax. Nut oil, which is frequently used for the same purpose, is expressed from walnuts.

Olive oil is that which is best adapted to culinary purposes.

Caroline. And what are the oils used for burning?

Mrs. B. Animal oils most commonly; but the preference given to them is owing to their being less expensive; for vegetable oils burn equally well, and are more pleasant, as their smell is not offensive.

Emily. Since oil is so good a combustible, what is the reason that lamps so frequently require trimming?

Mrs. B. This sometimes proceeds from the construction of the lamp, which may not be sufficiently favourable to a perfect combustion; but there is certainly a defect in the nature of oil itself, which renders it necessary for the best-constructed lamps to be occasionally trimmed. This defect arises from a portion of mucilage which it is extremely difficult to separate from the oil, and which being a bad combustible, gathers round the wick, and thus impedes its combustion, and consequently dims the light.

Caroline. But will not oils burn without a wick?

Mrs. B. Not unless their temperature be elevated to five or six hundred degrees; the wick answers this purpose, as I think I once before explained to you. The oil rises between the fibres of the cotton by capillary attraction, and the heat of the burning wick volatilises it, and brings it successively to the temperature at which it is combustible.

Emily. I suppose the explanation which you have given with regard to the necessity of trimming lamps, applies also to candles, which so often require snuffing?

Mrs. B. I believe it does; at least, in some degree. But besides the circumstance just explained, the common sort of oils are not very highly combustible, so that the heat produced by a candle, which is a coarse kind of animal oil, being insufficient to volatilise them completely, a quantity of soot is gradually deposited on the wick, which dims the light, and retards the combustion.

Caroline. Wax candles then contain no incombustible matter, since they do not require snuffing?

Mrs. B. Wax is a much better combustible than tallow, but still not perfectly so, since it likewise contains some particles that are unfit for burning; but when these gather round the wick, (which in a wax light is comparatively small,) they weigh it down on one side, and fall off together with the burnt part of the wick.

Caroline. As oils are such good combustibles, I wonder that they should require so great an elevation of temperature before they begin to burn?

Mrs. B. Though fixed oils will not enter into actual combustion below the temperature of about four hundred degrees,* yet they will slowly absorb oxygen at the common temperature of the atmosphere. Hence arises a variety of changes in oils which modify their properties and uses in the arts.

If oil simply absorbs, and combines with oxygen, it thickens and changes to a kind of wax. This change is observed to take place on the external parts of certain vegetables, even during their life. But it happens in many instances that the oil does not retain all the oxygen which it attracts, but that part of it combines with, or burns, the hydrogen of the oil, thus forming a quantity of water, which gradually goes off by evaporation. In this case the alteration of the oil consists not only in the addition of a certain quantity of oxygen, but in the diminution of the hydrogen. These oils are distinguished by the name of *drying oils.* Linseed, poppy, and nut-oils, are of this description.

Emily. I am well acquainted with drying oils, as I continually use them in painting. But I do not understand why the acquisition of oxygen on one hand, and a loss of hydrogen on the other, should render them drying?

Mrs. B. This, I conceive, may arise from two reasons; either from the oxygen which is added being less favourable to the state of fluidity than the hydrogen, which is subtracted; or from this additional quantity of oxygen giving rise to new combinations, in consequence of which the most fluid parts of the oil are liberated and volatilised.

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* This statement is too low. None of the fixed oils boil at a less temperature than 600 degrees, nor will they burn until converted into vapour; consequently they cannot burn at a lower temperature than 600. C.

For the purpose of painting, the drying quality of oil is further increased by adding a quantity of oxyd of lead to it, by which means it is more rapidly oxygenated.

The rancidity of oil is likewise owing to their oxygenation. In this case a new order of attraction takes place, from which a peculiar acid is formed, called the *sebacic acid.*

Caroline. Since the nature and composition of oil is so well known, pray could not oil be actually *made,* by combining its principles?

Mrs. B. That is by no means a necessary consequence; for there are innumerable varieties of compound bodies which we can decompose, although we are unable to reunite their ingredients. This, however, is not the case with oil, as it has very lately been discovered, that it is possible to form oil, by a peculiar process, from the action of oxygenated muriatic acid gas on hydro-carbonate.*

We now pass to the *volatile* or *essential oils.* These form the basis of all the vegetable perfumes, and are contained, more or less, in every part of the plant excepting the seed; they are, at least, never found in that part of the seed which contains the embrio plant.

Emily. The smell of flowers, then, proceeds from volatile oil?

Mrs. B. Certainly; but this oil is often most abundant in the rind of fruits, as in oranges, lemons, &c. from which it may be extracted by the slightest pressure; it is found also in the leaves of plants, and even in the wood.

Caroline. Is it not very plentiful in the leaves of mint, and of thyme, and all the sweet-smelling herbs?

Mrs. B. Yes, remarkably so; and in geranium leaves also, which have a much more powerful odour than the flowers.

The perfume of sandal fans is an instance of its existence in wood. In short, all vegetable odours or perfumes are produced by the evaporation of particles of these volatile oils.

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* Hydro-carbonate, is also called *olefiant* or *oil making* gas, on account of the supposed property here mentioned. But later experiments have shown that the substance it forms with chlorine, is not an oil, but a kind of ether, hence it is now known under the name of *chloric ether.* C.

Emily. They are, I suppose, very light, and of very thin consistence, since they are so volatile?

Mrs. B. They vary very much in this respect, some of them being as thick as butter, whilst others are as fluid as water. In order to be prepared for perfumes, or essences, these oils are first properly purified, and then either distilled with spirit of wine, as is the case with lavender water, or simply mixed with a large proportion of water, as is often done with regard to peppermint. Frequently, also, these odoriferous waters are prepared merely by soaking the plants in water, and distilling. The water then comes over impregnated with the volatile oil.

Caroline. Such waters are frequently used to take spots of grease out of cloth, or silk; how do they produce that effect?

Mrs. B. By combining with the substance that forms these stains; for volatile oils, and likewise the spirit in which they are distilled, will dissolve wax, tallow, spermaceti, and resins; if, therefore, the spot proceeds from any of these substances, it will remove it. Insects of every kind have a great aversion to perfumes, so that volatile oils are employed with success in museums for the preservation of stuffed birds and other species of animals.

Caroline. Pray does not the powerful smell of camphor proceed from a volatile oil?

Mrs. B. *Camphor* seems to be a substance of its own kind, remarkable by many peculiarities. But if not exactly of the same nature as volatile oil, it is at least very analogous to it. It is obtained chiefly from the camphor-tree, a species of laurel which grows in China, and in the Indian isles, from the stem and roots of which it is extracted.* Small quantities have also been distilled from thyme, sage, and other aromatic plants; and it is deposited in pretty large quantities by some volatile oils after long standing. It is extremely volatile and inflammable. It is insoluble in water, but is soluble in oils, in which state, as well as in its solid form, it is frequently applied to medicinal purposes. Amongst the particular properties of camphor, there is one too singular to be passed over in silence. If you take a small piece of camphor, and place it on the surface of a bason of pure water, it will immediately begin to move round and round with great rapidity; but if you pour into the basin a single drop of any odoriferous fluid, it will instantly put a stop to this motion. You can at any time try this very simple experiment; but you must not expect that I shall be able to account for this phenomenon, as nothing satisfactory has yet been advanced for its explanation.

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* Camphor comes chiefly from Japan. It is obtained by distilling the wood of the *laurus camphora*, or camphor tree, with water, in large iron pots, with earthen caps stuffed with straw. The camphor sublimes and concretes upon the straw. C.

Caroline. It is very singular indeed; and I will certainly try the expertment. Pray what are *resins*, which you just now mentioned?

Mrs. B. They are volatile oils, that have been acted on, and peculiarly modified, by oxygen.

Caroline. They are, therefore, oxygenated volatile oils?

Mrs. B. Not exactly; for the process does not appear to consist so much in the oxygenation of the oil, as in the combustion of a portion of its hydrogen, and a small portion of its carbon. For when resins are artificially made by the combination of volatile oils with oxygen, the vessel in which the process is performed is bedewed with water, and the air included within is loaded with carbonic acid.

Emily. This process must be, in some respects, similar to that for preparing drying oils?

Mrs. B. Yes; and it is by this operation that both of them acquire a greater degree of consistence. Pitch, tar, and turpentine, are the most common resins; they exude from the pine and fir trees. Copal, mastic, and frankincense, are also of this class of vegetable substances.

Emily. Is it of these resins that the mastic and copal varnishes, so much used in painting, are made?

Mrs. B. Yes. Dissolved either in oil, or in alcohol, resins form varnishes. From these solutions they may be precipitated by water, in which they are insoluble. This I can easily show you.—If you will pour some water into this glass of mastic varnish, it will combine with the alcohol in which the resin is dissolved, and the latter will be precipitated in the form of a white cloud—

Emily. It is so. And yet how is it that pictures or drawings, varnished with this solution, may safely be washed with water?

Mrs. B. As the varnish dries, the alcohol evaporates, and the dry varnish or resin w[illegible] remains, not being soluble in water, will not be acted on by [illegible]

There is a class of compound resins called *gum resins*, which are precisely what their name denotes, that is to say, resins combined with mucilage. Myrrh and assafœtida are of this description.

Caroline. Is it possible that a substance of so disagreeable a smell as assafœtida can be formed from a volatile oil?

Mrs. B. The odour of volatile oils is by no means always grateful. Onions and garlic derive their smell from volatile oils, as well as roses and lavender.

There is still another form under which volatile oils present themselves, which is that of *balsams*. These consist of resinous juices combined with a peculiar acid, called the benzoic acid. Balsams appear to have been originally volatile oils,* the oxygenation of which has converted one part into a resin, and the other part into an acid, which, combined together, form a balsam; such are the balsams of Peru, Tolu, &c.

We shall now take leave of the oils and their various modifications, and proceed to the next vegetable substance, which is *caoutchouc*. This is a white milky glutinous fluid, which acquires consistence, and blackens in drying, in which state it forms the substance with which you are so well acquainted, under the name of gum-elastic.

Caroline. I am surprised to hear that gum-elastic was ever white, or ever fluid! And from what vegetable is it procured?

Mrs. B. It is obtained from two or three different species of trees, in the East-Indies, and South-America, by making incisions in the stem. The juice is collected as it trickles from these incisions, and moulds of clay, in the form of little bottles of gum-elastic, are dipped into it. A layer of this juice adheres to the clay and dries on it: and several layers are successively added by repeating this till the bottle is of sufficient thickness. It is then beaten to break down the clay, which is easily shaken out. The natives of the countries where this substance is produced sometimes make shoes and boots of it by a similar process, and they are said to be extremely pleasant and serviceable, both from their elasticity, and their being waterproof.

The substance which comes next in our enumeration of the immediate ingredients of vegetables, is *extractive matter*. This is a term, which, in a general sense, may be applied to any substance extracted from vegetables; but it is more particularly understood to relate to the extractive *colouring matter* of plants. A great variety of colours are prepared from the vegetable kingdom, both for the purposes [illegible]inting and of dying; all the colours called *lakes* are of t[illegible]escription; but they are less durable than mineral colours, for, by long exposure to the atmosphere, they either darken or turn yellow.

Emily. I know that in painting, the lakes are reckoned far less durable colours than the ochres; but what is the reason of it?

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* This is an erroneous idea. Balsams are original and peculiar substances, and consist chiefly of resinous matter in a semifluid state. The benzoic acid is most probably formed during the process by which it is obtained. C.

Mrs. B. The change which takes place in vegetable colours is owing chiefly to the oxygen of the atmosphere slowly burning their hydrogen, and leaving, in some measure, the blackness of the carbon exposed. Such changes cannot take place in ochre, which is altogether a mineral substance.

Vegetable colours have a stronger affinity for animal than for vegetable substances, and this is supposed to be owing to a small quantity of nitrogen which they contain. Thus, silk and worsted will take a much finer vegetable dye than linen and cotton.

Caroline. Dying, then, is quite a chemical process?

Mrs. B. Undoubtedly. The condition required to form a good dye is, that the colouring matter should be precipitated, or fixed, on the substance to be dyed, and should form a compound not soluble in the liquids to which it will probably be exposed. Thus, for instance, printed or dyed linens or cottons must be able to resist the action of soap and water, to which they must necessarily be subject in washing; and woollens and silks should withstand the action of grease and acids, to which they may accidentally be exposed.

Caroline. But if linen and cotton have not a sufficient affinity for colouring matter, how are they made to resist the action of washing, which they always do when they are well printed?

Mrs. B. When the substance to be dyed has either no affinity for the colouring matter, or not sufficient power to retain it, the combination is effected, or strengthened, by the intervention of a third substance, called a *mordant*, or basis. The mordant must have a strong affinity both for the colouring matter and the substance to be dyed, by which means it causes them to combine and adhere together.

Caroline. And what are the substances that perform the office of thus reconciling the two adverse parties?

Mrs. B. The most common mordant is sulphat of alumine, or alum. Oxyds of tin and iron, in the state of compound salts, are likewise used for that purpose.

Tannin is another vegetable ingredient of great importance in the arts. It is obtained chiefly from the bark of trees; but it is found also in nut-galls, and in some other vegetables.

Emily. Is that the substance commonly called *tan*, which is used in hot-houses?

Mrs. B. Tan is the prepared bark in which the peculiar substance, tannin, is contained. But the use of tan in hot-houses is of much less importance than in the operation of *tanning*, by which the skin is converted into leather.

Emily. Pray, how is this operation performed ?

Mrs. B. Various methods are employed for this purpose, which all consist in exposing skin to the action of tannin, or of substances containing this principle, in sufficient quantities, and disposed to yield it to the skin. The most usual way is to infuse coarsely powdered oak bark in water, and to keep the skin immersed in this infusion for a certain length of time. During this process, which is slow and gradual, the skin is found to have increased in weight, and to have acquired a considerable tenacity and impermeability to water. This effect may be much accelerated by using strong saturations of the tanning principle (which can be extracted from bark,) instead of employing the bark itself. But this quick mode of preparation does not appear to make equally good leather.

Tannin is contained in a great variety of astringent vegetable substances, as galls, the rose-tree, and wine ; but it is no where so plentiful as in bark. All these substances yield it to water, from which it may be precipitated by a solution of isinglass, or glue, with which it strongly unites and forms an insoluble compound. Hence its valuable property of combining with skin, (which consists chiefly of glue,) and of enabling it to resist the action of the water.

Emily. Might we not see that effect by pouring a little melted isinglass into a glass of wine, which you say contains tannin ?

Mrs. B. Yes. I have prepared a solution of isinglass for that very purpose.—Do you observe the thick muddy precipitate ?—That is the tannin combined with the isinglass.

Caroline. This precipitate must then be of the same nature as leather ?

Mrs. B. It is composed of the same ingredients ; but the organisation and texture of the skin being wanting, it has neither the consistence nor the tenacity of leather.

Caroline. One might suppose that men who drink large quantities of red wine, stand a chance of having the coats of their stomachs converted into leather, since tannin has so strong an affinity for skin ?

Mrs. B. It is not impossible but that the coats of their stomachs may be, in some measure, tanned, or hardened by the constant use of this liquor ; but you must remember that where a number of other chemical agents are concerned, and, above all, where life exists, no certain chemical inference can be drawn.

I must not dismiss this subject, without mentioning a recent discovery of Mr. Hatchett, which relates to it. This gentleman found that a substance very similar to tannin, possessing all its leading properties, and actually capable of tanning leather, may be produced by exposing carbon, or any substance containing carbonaceous matter, whether vegetable, animal, or mineral, to the action of nitric acid.*

Caroline. And is not this discovery very likely to be of use to manufactures?

Mrs. B. That is very doubtful, because tannin, thus artificially prepared, must probably always be more expensive than that which is obtained from bark. But the fact is extremely curious, as it affords one of those very rare instances of chemistry being able to imitate the proximate principles of organised bodies.

The last of the vegetable materials is *woody fibre;* it is the hardest part of plants. The chief source from which this substance is derived is wood, but it is also contained, more or less, in every solid part of the plant. It forms a kind of skeleton of the part to which it belongs, and retains its shape after all the other materials have disappeared. It consists chiefly of carbon, united with a small proportion of salts, and the other constituents common to all vegetables.

Emily. It is of woody fibre, then, that the common charcoal is made?

Mrs. B. Yes. Charcoal, as you may recollect, is obtained from wood, by the separation of all its evaporable parts.

Before we take leave of the vegetable materials, it will be proper, at least, to enumerate the several vegetable acids which we either have had, or may have occasion to mention. I believe I formerly told you that their basis, or radical, was uniformly composed of hydrogen and carbon, and that their difference consisted only in the various proportions of oxygen which they contained.

The following are the names of the vegetable acids:

The *mucous acid,* obtained from gum or mucilage;
Suberic - - from cork;

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* To make artificial tannin, Mr Hatchett used 100 grains of charcoal with 500 of nitric acid, diluted with twice its weight of water, This mixture was heated and then suffered to digest for two days; more acid was then added, and the digestion continued untill the charcoal was dissolved. The solution being evaporated to dryness, leaves a dark brown mass. This is the tannin in question. Its taste is bitter and highly astringent. C.

Camphoric - - from camphor;
Benzoic - - from balsams;
Gallic - - from galls, bark, &c.
Malic - - from ripe fruits,
Citric - - from lemon juice;
Oxalic - - from sorrel;
Succinic - - from amber;
Tartarous - - from tartrit of potash;
Acetic - - from vinegar.

They are all decomposable by heat, soluble in water, and turn vegetable blue colours red. The *succinic*, the *tartarous*, and the *acetous acids*, are the products of the decomposition of vegetables, we shall, therefore, reserve their examination for a future period.

The *oxalic acid*, distilled from sorrel, is the highest term of vegetable acidification; for, if more oxygen be added to it, it loses its vegetable nature, and is resolved into carbonic acid and water; therefore, though all the other acids may be converted into the oxalic by an addition of oxygen, the oxalic itself is not susceptible of a further degree of oxygenation; nor can it be made, by any chemical processes, to return to a state of lower acidification.*

To conclude this subject, I have only to add a few words on the *gallic acid* . . .

Caroline. Is not this the same acid before mentioned, which forms ink, by precipitating sulphat of iron from its solution?

Mrs. B. Yes. Though it is usually extracted from galls, on account of its being most abundant in that vegetable substance, it may also be obtained from a great variety of plants. It constitutes what is called the *astringent principle* of vegetables; it is generally combined with tannin, and you will find that an infusion of tea, coffee, bark, red wine, or any vegetable substance that contains the astrinuent principle, will make a black precipitate with a solution of sulphat of iron.

Caroline. But pray what are galls?

Mrs. B. They are excrescences which grow on the bark of young oaks, and are occasioned by an insect which wounds the bark of trees, and lays its eggs in the aperture. The lacerated vessels of the tree then discharge their contents, and form an excrescence, which affords a defensive covering for these eggs. The insect, when come to life, first feeds on this excrescence, and some time afterwards eats its way out, as it appears from a hole which is formed in all gall-nuts that no longer contain an insect. It is in hot climates only that strongly astringent gall-nuts are found; those which are used for the purpose of making ink are brought from Aleppo.

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* *Oxalic acid* may be formed artificially. Put one ounce of white sugar, powdered, into a retort, and pour on three ounces of nitric acid. When the solution is over, make the liquor boil, and when it acquires a reddish-brown colour, add three ounces more of nitric acid. Continue the boiling untill the fumes cease, and the colour of the liquor vanishes. Then let the liquor be poured into a wide vessel, and on cooling, white, slender crystals will be formed. These are oxalic acid.
C.

Emily. But are not the oak-apples, which grow on the leaves of the oak in this country, of a similar nature?

Mrs. B. Yes; only they are an inferior species of galls, containing less of the astringent principle, and therefore less applicable to useful purposes.

Caroline. Are the vegetable acids never found but in their pure uncombined state?

Mrs. B. By no means; on the contrary, they are frequently met with in the state of compound salts; these, however, are in general not fully saturated with the salifiable bases, so that the acid predominates; and, in this state, they are called *acidulous* salts. Of this kind is the salt called cream of tartar.

Caroline. Is not the salt of lemon, commonly used to take out ink-spots and stains, of this nature?

Mrs. B. No; that salt consists of the oxalic acid, combined with a little potash. It is found in that state in sorrel.

Caroline. And pray how does it take out ink-spots?

Mrs. B. By uniting with the iron, and rendering it soluble in water.

Besides the vegetable materials which we have enumerated, a variety of other substances, common to the three kingdoms, are found in vegetables, such as potash, which was formerly supposed to belong exclusively to plants, and was, in consequence, called the vegetable alkali.

Sulphur, phosphorus, earths, and a variety of metallic oxyds, are also found in vegetables, but only in small quantities. And we meet sometimes with neutral salts, formed by the combination of these ingredients.

CONVERSATION XXI.

ON THE DECOMPOSITION OF VEGETABLES.

Caroline. THE account which you have given us, Mrs. B., of the materials of vegetables, is, doubtless, very instructive but it does not completely satisfy my curiosity. I wish to know how plants obtain the principles from which their various materials are formed; by what means these are converted into vegetable matter, and how they are connected with the life of the plant?

Mrs. B. This implies nothing less than a complete history of the chemistry and physiology of vegetation, subjects on which we have yet but very imperfect notions. Still I hope that I shall be able, in some measure, to satisfy your curiosity. But, in order to render the subject more intelligible, I must first make you acquainted with the various changes which vegetables undergo, when the vital power no longer enables them to resist the common laws of chemical attraction.

The composition of vegetables being more complicated than that of minerals, the former more readily undergo chemical changes than the latter: for the greater the variety of attractions, the more easily is the equilibrium destroyed, and a new order of combinations introduced.

Emily. I am surprised that vegetables should be so easily susceptible of decomposition; for the preservation of the vegetable kingdom is certainly far more important than that of minerals.

Mrs. B. You must consider, on the other hand, how much more easily the former is renewed than the latter. The decomposition of the vegetable takes place only after the death of the plant, which, in the common course of nature, happens when it has yielded fruit and seeds to propagate its species. If, instead of thus finishing its career, each plant was to retain its form and vegetable state, it would become an useless burden to the earth and its inhabitants. When vegetables, therefore, cease to be productive, they cease to live, and nature then begins her process of decomposition, in order to resolve them into their chemical constituents, hydrogen, carbon, and oxygen; those simple and primitive ingredients, which she keeps in store for all her combinations.

Emily. But since no system of combination can be destroyed, except by the establishment of another order of attractions, how can the decomposition of vegetables reduce them to their simple elements?

Mrs. B. It is a very long process, during which a variety of new combinations are successively established and successively destroyed; but, in each of these changes, the ingredients of vegetable matter tend to unite in a more simple order of compounds, till they are at length brought to their elementary state, or at least, to their most simple order of combinations. Thus you will find that vegetables are in the end almost entirely reduced to water and carbonic acid; the hydrogen and carbon dividing the oxygen between them, so as to form with it these two substances. But the variety of intermediate combinations that take place during the several stages of the decomposition of vegetables, present us with a new set of compounds, well worthy of our examination.

Caroline. How is it possible that vegetables, while putrefying, should produce any thing worthy of observation?

Mrs. B. They are susceptible of undergoing certain changes before they arrive at the state of putrefaction, which is the final term of decomposition; and of these changes we avail ourselves for particular and important purposes. But, in order to make you understand this subject, which is of considerable importance, I must explain it more in detail.

The decomposition of vegetables is always attended by a violent internal motion, produced by the disunion of one order of particles, and the combination of another. This is called FERMENTATION. There are several periods at which this process stops, so that a state of rest appears to be restored, and the new order of compounds fairly established. But, unless means be used to secure these new combinations in their actual state, their duration will be but transient, and a new fermentation will take place, by which the compound last formed will be destroyed; and another, and less complex order, will succeed.

Emily. The fermentations, then, appear to be only the successive steps by which a vegetable descends to its final dissolution.

Mrs. B. Precisely so. Your definition is perfectly correct.

Caroline. And how many fermentations, or new arrangements, does a vegetable undergo before it is reduced to its simple ingredients?

Mrs. B. Chemists do not exactly agree in this point; but there are, I think, four distinct fermentations, or periods, at which the decomposition of vegetable matter stops and changes its course. But every kind of vegetable matter is not equally susceptible of undergoing all these fermentations.

There are likewise several circumstances required to produce fermentation. Water and a certain degree of heat are both essential to this process, in order to separate the particles, and thus weaken their force of cohesion, that the new chemical affinities may be brought into action.

Caroline. In frozen climates, then, how can the spontaneous decomposition of vegetables take place?

Mrs. B. It certainly cannot; and, accordingly, we find scarcely any vestiges of vegetation where a constant frost prevails.

Caroline. One would imagine that, on the contrary, such spots would be covered with vegetables; for, since they cannot be decomposed, their number must always increase.

Mrs. B. But, my dear, heat and water are quite as essential to the formation of vegetables, as they are to their decomposition. Besides, it is from the dead vegetables, reduced to their elementary principles, that the rising generation is supplied with sustenance. No young plant, therefore, can grow unless its predecessors contribute both to its formation and support; and these not only furnish the seed from which the new plant springs, but likewise the food by which it is nourished.

Caroline. Under the torrid zone, therefore, where water is never frozen, and the heat is very great, both the processes of vegetation and of fermentation must, I suppose, be extremely rapid?

Mrs. B. Not so much as you imagine: for in such climates great part of the water which is required for these processes is in an aëriform state, which is scarcely more conducive either to the growth or formation of vegetables than that of ice. In those latitudes, therefore, it is only in low damp situations, sheltered by woods from the sun's rays, that the smaller tribes of vegetables can grow and thrive during the dry season, as dead vegetables seldom retain water enough to produce fermentation, but are, on the contrary, soon dried up by the heat of the sun, which enables them to resist that process; so that it is not till the fall of the autumnal rains (which are very violent in such climates,) that spontaneous fermentation can take place.

The several fermentations derive their names from their principal products. The first is called the *saccharine fermentation,* because its product is *sugar.*

Caroline. But sugar, you have told us, is found in all vegetables; it cannot, therefore, be the product of their decomposition.

Mrs. B. It is true that this fermentation is not cofined to the decomposition of vegetables, as it continually takes place during their life; and, indeed, this circumstance has, till lately, prevented it from being considered as one of the fermentations. But the process appears so analogous to the other fermentations, and the formation of sugar, whether in living or dead vegetable matter is so evidently a new compound, proceeding from the destruction of the previous order of combinations, and essential to the subsequent fermentations, that it is now, I believe, generally esteemed the first step, or necessary preliminary, to decomposition, if not an actual commencement of that process.

Caroline. I recollect your hinting to us that sugar was supposed not to be secreted from the sap, in the same manner as mucilage, fecula, oil, and the other ingredients of vegetables.

Mrs. B. It is rather from these materials, than from the sap itself, that sugar is formed; and it is developed at particular periods, as you may observe in fruits, which become sweet in ripening, sometimes even after they have been gathered. Life, therefore, is not essential to the formation of sugar, whilst on the contrary, mucilage, fecula, and the other vegetable materials that are secreted from the sap by appropriate organs, whose powers immediately depend on the vital principle, cannot be produced but during the existence of that principle.

Emily. The ripening of fruits is, then, their first step to destruction, as well as their last towards perfection?

Mrs. B. Exactly.—A process analogous to the saccharine fermentation takes place also during the cooking of certain vegetables. This is the case with parsnips, carrots, potatoes, &c. in which sweetness is developed by heat and moisture; and we know that if we carry the process a little farther, a more complete decomposition would ensue. The same process takes place also in seeds previous to their sprouting.

Caroline. How do you reconcile this to your theory, Mrs. B.? Can you suppose that a decomposition is the necessary precursor of life?

Mrs. B. That is indeed the case. The materials of the seed must be decomposed, and the seed disorganized, before a plant can sprout from it. Seeds, besides the embrio plant, contain (as we have already observed) fecula, oil, and a little mucilage. These substances are destined for the nourishment of the future plant; but they undergo some change before they can be fit for this function. The seeds, when buried in the earth, with a certain degree of moisture and of temperature, absorb water, which dilates them, separates their particles, and introduces a new order of attractions, of which sugar is the product. The substance of the seed is thus softened, sweetened, and converted into a sort of white milky pulp, fit for the nourishment of the embrio plant.

The saccharine fermentation of seeds is artificially produced, for the purpose of making *malt*, by the following process:—A quantity of barley is first soaked in water for two or three days: the water being afterwards drained off, the grain heats spontaneously, swells, bursts, sweetens, shows a disposition to germinate, and actually sprouts to the length of an inch, when the process is stopped by putting it into a kiln, where it is well dried at a gentle heat. In this state it is crisp and friable, and constitutes the substance called *malt*, which is the principal ingredient of beer.

Emily. But I hope you will tell us how malt is made into beer?

Mrs. B. Certainly; but I must first explain to you the nature of the second fermentation, which is essential to that operation. This is called the *vinous fermentation*, because its product is *wine*.

Emily. How very different the decomposition of vegetables is from what I had imagined! The products of their disorganisation appear almost superior to those which they yield during their state of life and perfection.

Mrs. B. And do you not, at the same time, admire the beautiful economy of Nature, which, whether she creates, or whether she destroys, directs all her operations to some useful and benevolent purpose?—It appears that the saccharine fermentation is extremely favourable, if not absolutely essential, as a previous step, to the vinous fermentation; so that if sugar be not developed during the life of the plant, the saccharine fermentation must be artificially produced before the vinous fermentation can take place. This is the case with barley, which does not yield any sugar until it is made into malt; and it is in that state only that it is susceptible of undergoing the vinous fermentation by which it is converted into beer.

Caroline. But if the product of the vinous fermentation is always wine, beer cannot have undergone that process, for beer is certainly not wine.

Mrs. B. Chemically speaking, beer may be considered as the wine of grain. For it is the product of the fermentation of malt, just as wine is that of the fermentation of grapes, or other fruits.

The consequence of the vinous fermentation is the decomposition of the saccharine matter, and the formation of a spirituous liquor from the constituents of the sugar. But, in order to promote this fermentation, not only water and a certain degree of heat are necessary, but also some other vegetable ingredients, besides the sugar, as fecula, mucilage, acids, salts, extractive matter, &c. all of which seem to contribute to this process; and give to the liquor its peculiar taste.

Emily. It is, perhaps, for this reason that wine is not obtained from the fermentation of pure sugar; but that fruits are chosen for that purpose, as they contain not only sugar, but likewise the other vegetable ingredients which promote the vinous fermentation, and give the peculiar flavour.

Mrs. B. Certainly. And you must observe also, that the relative quantity of sugar is not the only circumstance to be considered in the choice of vegetable juices for the formation of wine, otherwise the sugar-cane would be best adapted for that purpose. It is rather the manner and proportion in which the sugar is mixed with other vegetable ingredients that influences the production and qualities of wine. And it is found that the juice of the grape not only yields the most considerable proportion of wine, but that it likewise affords it of the most grateful flavour.

Emily. I have seen a vintage in Switzerland, and I do not recollect that heat was applied, or water added, to produce the fermentation of the grapes.

Mrs. B. The common temperature of the atmosphere in the cellars in which the juice of the grape is fermented is sufficiently warm for this purpose; and as the juice contains an ample supply of water, there is no occasion for any addition of it. But when fermentation is produced in dry malt, a quantity of water must necessarily be added.

Emily. But what are precisely the changes that happen during the vinous fermentation?

Mrs. B. The sugar is decomposed, and its constituents are recombined into two new substances; the one a peculiar liquid substance, called *alcohol* or *spirit of wine*, which remains in the fluid; the other, carbonic acid gas, which escapes during the fermentation. Wine, therefore, as I before observed, in a general point of view, may be considered as a liquid of which alcohol constitutes the essential part. And the varieties of strength and flavour of the different kinds of wine are to be attributed to the different qualities of the fruits from which they are obtained, independently of the sugar.

Caroline. I am astonished to hear that so powerful a liquid as spirit of wine should be obtained from so mild a substance as sugar.

Mrs. B. Can you tell me in what the principal difference consists between alcohol and sugar?

Caroline. Let me reflect . . . . Sugar consists of carbon, hydrogen, and oxygen. If carbonic acid be subtracted from it, during the formation of alcohol, the latter will contain less carbon and oxygen than sugar does; therefore hydrogen must be the prevailing principle of alcohol.

Mrs. B. It is exactly so. And this very large proportion of hydrogen accounts for the lightness and combustible property of alcohol, and of spirits in general, all of which consist of alcohol variously modified.

Emily. And can sugar be recomposed from the combination of alcohol and carbonic acid?

Mrs. B. Chemists have never been able to succeed in effecting this; but from analogy, I should suppose such a recomposition possible. Let us now observe more particularly the phenomena that take place during the vinous fermentation. At the commencement of this process, heat is evolved; and the liquor swells considerably from the formation of the carbonic acid, which is disengaged in such prodigious quantities as would be fatal to any person who should unawares inspire it; an accident which has sometimes happened. If the fermentation be stopped by putting the liquor into barrels, before the whole of the carbonic acid is evolved, the wine is brisk, like Champagne, from the carbonic acid imprisoned in it, and it tastes sweet, like cyder, from the sugar not being completely decomposed.

Emily. But I do not understand why heat should be evolved during this operation. For, as there is a considerable formation of gas, in which a proportionable quantity of heat must become insensible, I should have imagined that cold, rather than heat, would have been produced.

Mrs. B. It appears so on first consideration; but you must recollect that fermentation is a complicated chemical process; and that, during the decompositions and recompositions attending it, a quantity of chemical heat may be disengaged, sufficient both to develope the gas, and to effect an increase of temperature. When the fermentation is completed, the liquid cools and subsides, the effervescence ceases, and the thick, sweet, sticky juice of the fruit is converted into a clear, transparent, spiritous liquor, called wine.

Emily. How much I regret not having been acquainted with the nature of the vinous fermentation, when I had an opportunity of seeing the process!

Mrs. B. You have an easy method of satisfying yourself in that respect by observing the process of brewing, which, in every essential circumstance, is similar to that of making wine, and is really a very curious chemical operation.

Although we cannot actually make wine at this moment, it will be easy to show you the mode of analyzing it. This is

Fig. 1.

- Fig. 2.

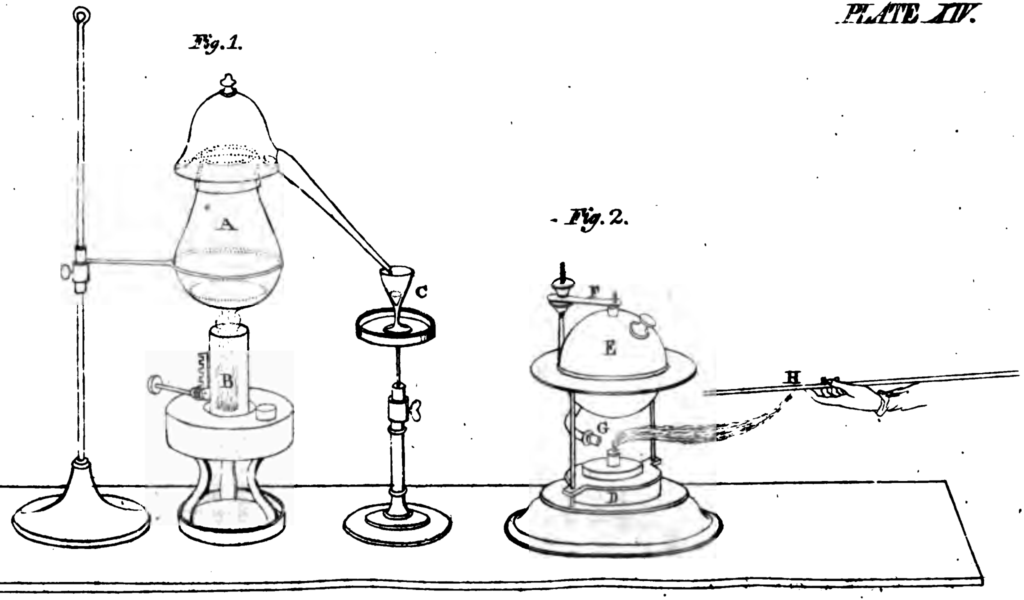

Fig. 1. A. Alembic.—B Lamp.—C Wine glass.—Fig. 2. Alcohol blowpipe.—D the Lamp.—E the vessel in which the Alcohol is boiling. F a safety valve.—G the inflamed jet or steam of alcohol directed towards a glass tube H.

done by distillation. When wine of any kind is submitted to this operation, it is found to contain brandy, water, tartar, extractive colouring matter, and some vegetable acids. I have put a little port wine into this alembic of glass (PLATE XIV. fig. 1.,) and on placing the lamp under it, you will soon see the spirit and water successively come over—

Emily. But you do not mention alcohol amongst the *products* of the distillation of wine; and yet that is its most essential ingredient?

Mrs. B. The alcohol is contained in the brandy which is now coming over, and dropping from the still. Brandy is nothing more than a mixture of alcohol and water; and in order to obtain the alcohol pure, we must again distil it from brandy.

Caroline. I have just taken a drop on my finger; it tastes like strong brandy, but it is without colour, whilst brandy is of a deep yellow.

Mrs. B. It is not so naturally; in its pure state brandy is colourless, and it obtains the yellow tint you observe, by extracting the colouring matter from the new oaken casks in which it is kept. But if it does not acquire the usual tinge in this way, it is the custom to colour the brandy used in this country artificially, with a little burnt sugar, in order to give it the appearance of having been long kept.

Caroline. And is rum also distilled from wine?

Mrs. B. By no means; it is distilled from the sugar-cane, a plant which contains so great a quantity of sugar, that it yields more alcohol than almost any other vegetable. After the juice of the cane has been pressed out for making sugar, what still remains in the bruised cane is extracted by water, and this watery solution of sugar is fermented, and produces rum.

The spirituous liquor called *arack* is in a similar manner distilled from the product of the vinous fermentation of rice.

Emily. But rice has no sweetness; does it contain any sugar?

Mrs. B. Like barley and most other seeds, it is insipid until it has undergone the saccharine fermentation; and this, you must recollect, is always a previous step to the vinous fermentation in those vegetables in which sugar is not already formed. Brandy may in the same manner be obtained from malt.

Caroline. You mean from beer, I suppose; for the malt must have previously undergone the vinous fermentation.

Mrs. B. Beer is not precisely the product of the vinous fermentation of malt. For hops are a necessary ingredient for the formation of that liquor; whilst brandy is distilled from pure fermented malt. But brandy might, no doubt, be distilled from beer as well as from any other liquor that has undergone the vinous fermentation; for since the basis of brandy is alcohol, it may be obtained from any liquid that contains that spirituous substance.

Emily. And pray, from what vegetable is the favourite spirit of the lower orders of the people, gin, extracted?

Mrs. B. The spirit (which is the same in all fermented liquors) may be obtained from any kind of grain; but the peculiar flavour which distinguishes gin is that of juniper berries, which are distilled together with the grain—

I think the brandy contained in the wine we are distilling must, by this time, be all come over. Yes—taste the liquid that is now dropping from the alembic—

Caroline. It is perfectly insipid, like water.

Mrs. B. It is water, which, as I was telling you, is the second product of wine, and comes over after all the spirit, which is the lightest part, is distilled.—The tartar and extractive colouring matter we shall find in a solid form at the bottom of the alembic.

Emily. They look very like the lees of wine.

Mrs. B. And in many respects they are of a similar nature, for lees of wine consist chiefly of tartrit of potash; a salt which exists in the juice of the grape, and in many other vegetables, and is developed only by the vinous fermentation. During this operation it is precipitated, and deposits itself on the internal surface of the cask in which the wine is contained. It is much used in medicine, and in various arts, particularly dying, under the name of *cream of tartar*, and it is from this salt that the tartarous acid is obtained.

Caroline. But the medicinal cream of tartar is in appearance quite different from these dark-coloured dregs; it is perfectly colourless.

Mrs. B. Because it consists of the pure salts only, in its crystallised form; whilst in the instance before us it is mixed with the deep-coloured extractive matter, and other foreign ingredients.

Emily. Pray cannot we now obtain pure alcohol from the brandy which we have distilled?

Mrs. B. We might; but the process would be tedious; for in order to obtain alcohol perfectly free from water, it is necessary to distil, or, as the distillers call it, *rectify* it several times. You must therefore allow me to produce a bottle of alcohol that has been thus purified. This is a very important ingredient, which has many striking properties, besides its forming the basis of all spirituous liquors.

Emily. It is alcohol, I suppose, that produces intoxication?

Mrs. B. Certainly; but the stimulus and momentary energy it gives to the system, and the intoxication it occasions when taken in excess, are circumstances not yet accounted for.

Caroline. I thought that it produced these effects by increasing the rapidity of the circulation of the blood; for drinking wine or spirits, I have heard, always quickens the pulse.

Mrs. B. No doubt; the spirit, by stimulating the nerves, increases the action of the muscles; and the heart, which is one of the strongest muscular organs, beats with augmented vigour, and propels the blood with accelerated quickness. After such a strong excitation, the frame naturally suffers a proportional degree of depression, so that a state of debility and languor is the invariable consequence of intoxication. But though these circumstances are well ascertained, they are far from explaining why alcohol should produce such effects.

Emily. Liquers are the only kind of spirits which I think pleasant. Pray of what do they consist?

Mrs. B. They are composed of alcohol, sweetened with syrup, and flavoured with volatile oil.

The different kinds of odoriferous spirituous waters are likewise solutions of volatile oil in alcohol, as lavender water, eau de Cologne, &c.

The chemical properties of alcohol are important and numerous. It is one of the most powerful chemical agents, and is particularly useful in dissolving a variety of substances, which are soluble neither by water nor heat.

Emily. We have seen it dissolve copal and mastic to form varnishes; and these resins are certainly not soluble in water, since water precipitates them from their solution in alcohol.

Mrs. B. I am happy to find that you recollect these circumstances so well. The same experiment affords also an instance of another property of alcohol,—its tendency to unite with water; for the resin is precipitated in consequence of losing the alcohol, which abandons it from its preference for water. It is attended also, as you may recollect, with the same peculiar circumstance of a disengagement of heat and consequent diminution of bulk, which we have supposed to be produced by a mechanical penetration of particles by which latent heat is forced out.

Alcohol unites thus readily not only with resins and with water, but with oils and balsams; these compounds form the extensive class of elixirs, tinctures, quintessences, &c.

Emily. I suppose that alcohol must be highly combustible, since it contains so large a proportion of hydrogen?

Mrs. B. Extremely so; and it will burn at a very moderate temperature.

Caroline. I have often seen both brandy and spirit of wine burnt; they produce a great deal of flame, but not a proportional quantity of heat, and no smoke whatever.*

Mrs. B. The last circumstance arises from their combustion being complete; and the disproportion between the flame and heat shows you that these are by no means synonymous.

The great quantity of flame proceeds from the combustion of the hydrogen to which you know, that manner of burning is peculiar.—Have you not remarked also that brandy and alcohol will burn without a wick?—They take fire at so low a temperature, that this assistance is not required to concentrate the heat and volatilise the fluid.

Caroline. I have sometimes seen brandy burnt by merely heating it in a spoon.

Mrs. B. The rapidity of the combustion of alcohol may, however, be prodigiously increased by first volatilising it. An ingenious instrument has been constructed on this principle to answer the purpose of a blow-pipe, which may be used for melting glass, or other chemical purposes. It consists of a small metallic vessel (PLATE XIII. fig. 2.) of a spherical shape, which contains the alcohol, and is heated by the lamp beneath it; as soon as the alcohol is volatilised, it passes through the spout of the vessel, and issues just above the wick of the lamp, which immediately sets fire to the stream of vapour as I shall show you—*

Emily. With what amazing violence it burns! The flame of alcohol, in the state of vapour, is, I fancy, much hotter than when the spirit is merely burnt in a spoon?

Mrs. B. Yes; because in this way the combustion goes on much quicker, and, of course, the heat is proportionally increased.—Observe its effect on this small glass tube, the middle of which I present to the extremity of the flame, where the heat is greatest.

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* A spirit lamp, which answers very well for bending small glass tubes, may be constructd by almost any one. Take a lo vial with a wide mouth. fit a cork to it and pierce the cork to admit a piece of glass tube, the bore of which is about the size of a large goosequill. Let the tube rise an inch or two above the cork—pass some cotton wick through the tube—then fill the vial with alcohol and put the cork and tube in their places. The lamp is then ready. C.

Caroline. The glass, in that spot, is become red hot, and bends from its own weight.

Mrs. B. I have not drawn it asunder, and am going to blow a ball at one of the heated ends: but I must previously close it up, and flatten it with this little metallic instrument, otherwise the breath would pass through the tube without dilating any part of it.—Now Caroline, will you blow strongly into the tube whilst the closed end is red hot.

Emily. You blowed too hard; for the ball suddenly dilated to a great size, and then burst in pieces.

Mrs. B. You will be more expert another time; but I must caution you, should you ever use this blow-pipe, to be very careful that the combustion of the alcohol does not go on with too great violence, for I have seen the flame sometimes dart out with such force as to reach the opposite wall of the room, and set the paint on fire. There is, however, no danger of the vessel bursting, as it is provided with a safety tube, which affords an additional vent for the vapour of alcohol when required.

The products of the combustion of alcohol consist in a great proportion of water, and a small quantity of carbonic acid. There is no smoke or fixed remains whatever.—How do you account for that, Emily?

Emily. I suppose that the oxygen which the alcohol absorbs in burning, converts its hydrogen into water and its carbon into carbonic acid gas, and thus it is completely consumed.

Mrs. B. Very well.—*Ether*, the lightest of all fluids, and with which you are well acquainted, is obtained from alcohol, of which it forms the lightest and most volatile part.

Emily. Eether, thn, is to alcohol, what alcohol is to brandy?

Mrs. B. No: there is an essential difference. In order to obtain alcohol from brandy, you need only deprive the latter of its water; but for the formation of ether, the alcohol must be decomposed, and one of its constituents partly subtracted. I leave you to guess which of them it is—

Emily. It cannot be hydrogen, as ether is more volatile than alcohol, and hydrogen is the lightest of all its ingredients; nor do I suppose that it can be oxygen, as alcohol contains so small a proportion of that principle; it is, therefore, most probably, carbon, a diminution of which would not fail to render the new compound more volatile.

Mrs. B. You are perfectly right. The formation of ether consists simply in subtracting from the alcohol a certain proportion of carbon; this is effected by the action of the sulphuric, nitric, or muriatic acids, on alcohol. The acid and carbon remain at the bottom of the vessel, whilst the decarbonised alcohol flies off in the form of a condensable vapour, which is ether.

Ether is the most inflammable of all fluids, and burns at so low a temperature that the heat evolved during its combustion is more than is required for its support, so that a quantity of ether is volatilised, which takes fire, and gradually increases the violence of the combustion.

Sir Humphry Davy has lately discovered a very singular fact respecting the vapour of ether. If a few drops of ether be poured into a wine-glass, and a fine platina wire, heated almost to redness, be held suspended in the glass, close to the surface of the ether; the wire soon becomes intensely red-hot, and remains so for any length of time. We may easily try the experiment. . . . .

Caroline. How very curious! The wire is almost white hot, and a pungent smell rises from the glass. Pray how is this accounted for?

Mrs. B. This is owing to a very peculiar property of the vapour of ether, and indeed of many other combustible gaseous bodies. At a certain temperature lower than that of ignition, these vapours undergo a slow and imperfect combustion, which does not give rise, in any sensible degree, to the phenomena of light and flame, and yet extricates a quantity of caloric sufficient to react upon the wire and make it red-hot, and the wire in its turn keeps up the effect as long as the emission of vapour continues.

This singular effect, which is also produced by alcohol, may be rendered more striking, and kept up for an indefinite length of time, by rolling a few coils of platina wire, of the diameter of from about 1-60th to 1-70th of an inch, round the wick of a spirit-lamp. If this lamp be lighted for a moment, and blown out again, the wire, after ceasing for an instant to be luminous, becomes red-hod again, though the lamp is extinguished, and remains glowing vividly, till the whole of the spirit contained in the lamp has been evaporated and consumed in this peculiar matter.

Caroline. That is extremely curious. But why should not an iron or silver wire produce the same effect?

Mrs. B. Because either iron or silver, being much better conductors of heat than platina, the heat is carried off too fast by those metals to allow the accumulation of caloric necessary to produce the effect in question.

Ether is so light that it evaporates at the common temperature of the atmosphere; it is therefore necessary to keep it confined by a well ground glass stopper. No degree of cold known has ever frozen it.*

Caroline. Is it not often taken medicinally?

Mrs. B. Yes; it is one of the most effectual antispasmodic medicines, and the quickness of its effects, as such, probably depends on its being instantly converted into vapour by the heat of the stomach, through the intervention of which it acts on the nervous system. But the frequent use of ether, like that of spirituous liquors, becomes prejudicial, and, if taken to excess, it produces effects similar to those of intoxication.

We may now take our leave of the vinous fermentation, of which I hope, you have acquired a clear idea; as well as of the several products that are derived from it.

Caroline. Though this process appears, at first sight, so much complicated, it may, I think, be summed up in a few words, as it consists in the conversion of sugar and fermentable bodies into alcohol and carbonic acid, which give rise both to the formation of wine, and of all kinds of spirituous liquors.

Mrs. B. We shall now proceed to the *acetous fermentation*, which is thus called, because it converts wine into vinegar, by the formation of the acetous acid, which is the basis or radical of vinegar.

Caroline. But is not the acidifying principle of the acetous acid the same as that of all other acids, oxygen?

Mrs. B. Certainly; and on that account the contact of air is essential to this fermentation, as it affords the necessary supply of oxygen. Vinegar, in order to obtain pure acetous acid from it, must be distilled and rectified by certain processes.

Emily. But pray, Mrs. B., is not the acetous acid frequently formed without this fermentation taking place? Is it not, for instance, contained in acid fruits, and in every substance that becomes sour?

Mrs. B. No, not in fruits; you confound it with the citric, the malic, the oxalic, and other vegetable acids, to which living vegetables owe their acidity. But whenever a vegetable substance turns sour, after it has ceased to live, the acetous acid is developed by means of the acetous fermentation, in which the substance advances a step towards its final decomposition.

Amongst the various instances of acetous fermentation, that of bread is usually classed.

Caroline. But the fermentation of bread is produced by yeast; how does that effect it?

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* Ether freezes, and shoots into crystals at 46° below the zero of Fahrenheit. C.

Mrs. B. It is found by experience that any substance that has already undergone a fermentation, will readily excite it in one that is susceptible of that process. If, for instance, you mix a little vinegar with wine, that is intended to be acidified, it will absorb oxygen more rapidly, and the process be completed much sooner, than if left to ferment spontaneously. Thus yeast, which is a product of the fermentation of beer, is used to excite and accelerate the fermentation of malt, which is to be converted into beer, as well as that of paste which is to be made into bread.

Caroline. But if bread undergoes the acetous fermentation, why is it not sour?

Mrs. B. It acquires a certain savour which corrects the heavy insipidity of flour, and may be reckoned a first degree of acidification; or if the process were carried further, the bread would become decidedly acid.

There are, however, some chemists who do not consider the fermentation of bread as being of the acetous kind, but suppose that it is a process of fermentation peculiar to that substance.

The *putrid fermentation* is the final operation of Nature, and her last step towards reducing organised bodies to their simplest combinations. All vegetables spontaneously undergo this fermentation after death, provided there be a sufficient degree of heat and moisture, together with access of air; for it is well known that dead plants may be preserved by drying, or by the total exclusion of air.

Caroline. But do dead plants undergo the other fermentation previous to this last; or do they immediately suffer the putrid fermentation?

Mrs. B. That depends on a variety of circumstances, such as the degrees of temperature and of moisture, the nature of the plant itself, &c. But if you were carefully to follow and examine the decomposition of plants from their death to their final dissolution, you would generally find a sweetness developed, in the seeds, and a spirituous flavour in the fruits (which have undergone the saccharine fermentation), previous to the total disorganisation and separation of the parts.

Emily. I have sometimes remarked a kind of spirituous taste in fruits that were over ripe, especially oranges; and this was just before they became rotten.

Mrs. B. It was then the vinous fermentation which had succeeded the saccharine, and had you followed up these changes attentively, you would probably have found the spiritous taste followed by acidity, previous to the fruit passing to the state of putrefaction.

When the leaves fall from the trees in autumn, they do not (if there is no great moisture in the atmosphere) immediately undergo a decomposition, but are first dried and withered; as soon, however, as the rain sets in, fermentation commences, their gaseous products are imperceptibly evolved into the atmosphere, and their fixed remains mixed with their kindred earth.

Wood, when exposed to moisture, also undergoes the putrid fermentation and becomes rotten.

Emily. But I have heard that the *dry rot*, which is so liable to destroy the beams of houses, is prevented by a current of air; and yet you said that air was essential to the putrid fermentation?

Mrs. B. True; but it must not be in such a proportion to the moisture as to dissolve the latter, and this is generally the case when the rotting of wood is prevented or stopped by the free access of air. What is commonly called dry rot, however, is not I believe a true process of putrefaction. It is supposed to depend on a peculiar kind of vegetation, which, by feeding on the wood, gradually destroys it.

Straw and all other kinds of vegetable matter undergo the putird fermentation more rapidly when mixed with animal matter. Much heat is evolved during this process, and a variety of volatile products are disengaged, as carbonic acid and hydrogen gas, the latter of which is frequently either sulphurated or phosphorated.—When all these gases have been evolved, the fixed products, consisting of carbon, salts, potash, &c. form a kind of vegetable earth, which makes very fine manure, as it is composed of those elements which form the immediate materials of plants.

Caroline. Pray are not vegetables sometimes preserved from decomposition by petrification? I have seen very curious specimens of petrified vegetables, in which state they perfectly preserve their form and organisation, though in appearance they are changed to stone.

Mrs. B. That is a kind of metamorphosis, which, now that you are tolerably well versed in the history of mineral and vegetable substances, I leave to your judgment to explain. Do you imagine that vegetables can be converted into stone?

Emily. No, certainly; but they might perhaps be changed to a substance in appearance resembling stone.

Mrs. B. It is not so, however, with the substances that are called petrified vegetables; for these are really stone, and generally of the hardest kind, consisting chiefly of silex.* The case is this; when a vegetable is buried under water, or in wet earth, it is slowly and gradually decomposed. As each successive particle of the vegetable is destroyed, its place is supplied by a particle of siliceous earth, conveyed thither by the water. In the course of time the vegetable is entirely destroyed, but the silex has completely replaced it, having assumed its form and apparent texture, as if the vegetable itself were changed to stone.

Caroline. That is very curious! and I suppose that petrified animal substances are of the same nature?

Mrs. B. Precisely. It is equally impossible for either animal or vegetable substances to be converted into stone. They may be reduced, as we find they are, by decomposition, to their constituent elements, but cannot be changed to elements, which do not enter into their composition.

There are, however, circumstances which frequently prevent the regular and final decomposition of vegetables; as, for instance, when they are buried either in the sea, or in the earth, where they cannot undergo the putrid fermenation for want of air. In these cases they are subject to a peculiar change, by which they are converted into a new class of compounds, called *bitumens.*

Caroline. These are substances I never heard of before.

Mrs. B. You will find, however, that some of them are very familiar to you. Bitumens are vegetables so far decomposed as to retain no organic appearance; but their origin is easily detected by their oily nature, their combustibility, the products of their analysis, and the impression of the forms of leaves, grains, fibres of wood, and even of animals, which they frequently bear.

They are sometimes of an oily liquid consistence, as the substance called *naptha,** in which we preserved potassium; it is a fine transparent colourless fluid, that issues out of clays in some parts of Persia. But more frequently bitumens are solid, as *osphaltum*, a smooth, hard, brittle substance, which easily melts, and forms, in its liquid state, a beautiful dark brown colour for oil painting. *Jet*, which is of a still harder texture, is a peculiar bitumen, susceptible of so fine a polish, that it is used for many ornamental purposes.

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* Petrifactions are of two kinds, viz. *silecious*, when flinty particles take the place of the original substance, and *calcareous* where the substance appears to be changed to lime-stone. The first kind gives fire with steel, and the other effervesces with acids. C.

Coal is also a bituminous substance, to the composition of which both the mineral and animal kingdoms seem to concur. This most useful mineral appears to consist chiefly of vegetable matter, mixed with the remains of marine animals and marine salts, and occasionally containing a quantity of sulphuret of iron, commonly called pyrites.

Emily. It is, I suppose, the earthy, the metallic, and the saline parts of coals, that compose the cinders or fixed products of their combustion; whilst the hydrogen and carbon, which they derive from vegetables, constitute their volatile products.

Caroline. Pray is not *coke*, (which I have heard is much used in some manufactures,) also a bituminous substance?

Mrs. B. No; it is a kind of fuel artificially prepared from coals. It consists of coals reduced to a substance analogous to charcoal, by the evaporation of their bituminous parts. Coke, therefore, is composed of carbon, with some earthy and saline ingredients.

Succin, or *yellow amber*, is a bitumen which the ancients called *electrum*, from whence the word electricity is derived, as that substance is peculiarly, and was once supposed to be exclusively, electric. It is found either deeply buried in the bowels of the earth, or floating on the sea, and is supposed to be a resinous body which has been acted on by sulphuric acid, as its analysis shows it to consist of an oil and an acid. The oil is called *oil of amber*, the acid the *succinic*.

Emily. That oil I have sometimes used in painting, as it is reckoned to change less than the other kinds of oils.

Mrs. B. The last class of vegetable substances that have changed their nature are *fossil-wood*, *peat*, and *turf*. These are composed of wood and roots of shrubs, that are partly decomposed by being exposed to moisture under ground, and yet, in some measure, preserve their form and organic appearance. The peat, or black earth of the moors, retains but few vestiges of the roots to which it owes its richness and combustibility, these substances being in the course of time reduced to the state of vegetable earth. But in turf the roots of plants are still discernible, and it equally answers the purpose of fuel. It is the combustible used by the poor in heathy countries, which supply it abundantly.

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* Naptha appears to be the only fluid in which oxygen does not exist; hence its property of preserving potassium which has so strong an affinity for oxygen as to absorb it from all other fluids. It however loses this property by exposure to the atmosphere, probably because it absorbs a small quantity of air, or moisture. It is again restored by distillation. C.

It is too late this morning to enter upon the history of vegetation. We shall reserve this subject, therefore, for our next interview, when I expect that it will furnish us with ample matter for another conversation.

CONVERSATION XXII.

HISTORY OF VEGETATION.

Mrs. B. THE VEGETABLE KINGDOM may be considered as the link which unites the mineral and animal creation into one common chain of beings; for it is through the means of vegetation alone that mineral substances are introduced into the animal system, since, generally speaking, it is from vegetables that all animals ultimately derive their sustenance.

Caroline. I do not understand that; the human species subsists as much on animal as on vegetable food, and there are some carnivorous animals that will eat only animal food.

Mrs. B. That is true; but you do not consider that those that live on animal food, derive their sustenance equally, though not so immediately, from vegetables. The meat that we eat is formed from the herbs of the field, and the prey of carnivorous animals proceeds, either directly or indirectly, from the same source. It is, therefore, through this channel that the simple elements become a part of the animal frame. We should in vain attempt to derive nourishment from carbon, hydrogen, and oxygen, either in their separate state, or combined in the mineral kingdom; for it is only by being united in the form of vegetable combination, that they become capable of conveying nourishment.

Emily. Vegetation, then, seems to be the method which Nature employs to prepare the food of animals?

Mrs. B. That is certainly its principal object. The vegetable creation does not exhibit more wisdom in that admirable system of organisation, by which it is enabled to answer its own immediate ends of preservation, nutrition, and propagation, than in its grand and ultimate object of forming those arrangements and combinations of principles, which are so well adapted for the nourishment of animals.

Emily. But I am very curious to know whence vegetables obtain their principles which form their immediate materials?

Mrs. B. This is a point on which we are yet so much in the dark, that I cannot hope fully to satisfy your curiosity; but what little I know on this subject, I will endeavour to explain to you.

The soil, which, at first view, appears to be the aliment of vegetables, is found, on a closer investigation, to be little more than the channel through which they receive their nourishment; so that it is very possible to rear plants without any earth or soil.*

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* The opinion that water is the only food of plants, was adopted by the learned on this subject in the 17th century; and many experiments were made which seemed to prove that this was the truth. Among others was a famous one by Van Helmout, which for a long time was supposed to have established the point beyond all doubt. He planted a willow which weighed five pounds, in an earthern vessel containing 200 lbs of dried earth. This vessel was sunk into the ground, and the tree was watered, sometimes with distilled, and sometimes with rain water.

At the end of five years the willow weighed 169 lbs; and on weighing the soil, dried as before, it was found to have lost only two ounces. Thus the willow had gained 164 lbs, and yet its food had been only water. The induction from this experiment was obvious. Plants live on pure water. This therefore was the general opinion, untill the progress of chemistry detected its fallacy. Bergman, in 1773 showed by some experiments that the water, which Van Helmout had used contained as much earth as could exist in the tree at the end of the five years; a pound of water containing about a grain of earth. So that this experiment by no means proved that the willow lived on water alone. Since this time a great variety of experiments have been made for the purpose of deciding what was the food of plants. In the course of these, it has been found, that although seeds do vegetate in pure distilled water, yet the plant is weakly, and finally dies before the fruit is matured.

It is pretty certain then that earth is absolutely necessary to the growth of plants, and that a part of their food is taken from the soil. Indeed, the well known fact that a soil is *worn out* by a long succession of crops, and finally becomes sterile, unless manured, is good proof that plants do absorb something from it.

Saussure has shown that this is the fact, and also that the earth, which is always found in plants, is of the same kind, as that on which they grow. Thus trees growing in a granitic soil contain a large proportion of silica, while those growing in a calcarious soil, contain little silica, but a great proportion of calcareous earth.

In addition to what plants absorb from the ground, there is no doubt but they obtain a part of their nourishment from water and air. Some experiments made at Berlin, show that wheat, barley, &c. contain a quantity of earth, though fed only on distilled water.

From the air plants absorb carbonic acid gas. The carbon they retain, which forms the greatest part of their bulk. The oxygen is emitted, and goes to purify the atmosphere.

Thus it is seen that plants obtain their food from the earth, from water, and from the air. C.

Caroline. Of that we have an instance in the hyacinth, and other bulbous roots, which will grow and blossom beautifully in glasses of water. But I confess I should think it would be difficult to rear trees in a similar manner.

Mrs. B. No doubt it would, as it is the burying of the roots in the earth that supports the stem of the tree. But this office, besides that of affording a vehicle for food, is far the most important part which the earthy portion of the soil performs in the process of vegetation; for we can discover, by analysis, but an extremely small proportion of earth in vegetable compounds.

Caroline. But if earths do not afford nourishment, why is it necessary to be so attentive to the preparation of the soil?

Mrs. B. In order to impart it those qualities which render it a proper vehicle for the food of the plant. Water is the chief nourishment of vegetables; if, therefore, the soil be too sandy, it will not retain a quantity of water sufficient to supply the roots of the plants. If, on the contrary, it abound too much with clay, the water will lodge in such quantities as to threaten a decomposition of the roots. Calcareous soils are, upon the whole, the most favourable to the growth of plants: soils are, therefore, usually improved by chalk, which, you may recollect, is a carbonat of lime. Different vegetables, however, require different kinds of soils. Thus rice demands a moist retentive soil; potatoes a soft sandy soil; wheat a firm and rich soil. Forest trees grow better in fine sand than in a stiff clay; and a light ferruginous soil is best suited to fruit-trees.

Caroline. But pray what is the use of manuring the soil?

Mrs. B. Manure consists of all kinds of substances, whether of vegetable or animal origin, which have undergone the putrid fermentation, and are consequently decomposed, or nearly so, into their elementary principles. And it is requisite that these vegetable matters should be in a state of decay, or approaching decomposition. The addition of calcareous earth, in the state of chalk or lime, is beneficial to such soils, as it accelerates the dissolution of vegetable bodies. Now, I ask you what is the utility of supplying the soil with these decomposed substances?

Caroline. It is, I suppose, in order to furnish vegetables with the principles which enter their composition. For manures not only contain carbon, hydrogen, and oxygen, but by their decomposition supply the soil with these principles in their elementary form.*

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* But what is the use of all this, if "water is the chief nourishment of vegetables?" C.

Mrs. B. Undoubtedly; and it is for this reason that the finest crops are produced in fields that were formerly covered with woods, because their soil is composed of a rich mould, a kind of vegetable earth which abounds in those principles.

Emily. This accounts for the plentifulness of the crops produced in America, where the country was but a few years since covered with wood.

Caroline. But how is it that animal substances are reckoned to produce the best manure? Does it not appear much more natural that the decomposed elements of vegetables should be the most appropriate to the formation of new vegetables?

Mrs. B. The addition of a much greater proportion of nitrogen, which constitutes the chief difference between animal and vegetable matter, renders the composition of the former more complicated, and consequently more favourable to decomposition. The use of animal substances is chiefly to give the first impulse to the fermentation of the vegetable ingredients that enter into the composition of manures. The manure of a farmyard is of that description; but there is scarcely any substance susceptible of undergoing the putrid fermentation that will not make good manure. The heat produced by the fermentation of manure is another circumstance which is extremely favourable to vegetation; yet this heat would be too great if the manure was laid on the ground during the height of fermentation; it is used in this state only for hot-beds to produce melons, cucumbers, and such vegetables as require a very high temperature.

Caroline. A difficulty has just occurred to me which I do not know how to remove. Since all organised bodies are, in the common course of nature, ultimately reduced to their elementary state, they must necessarily in that state enrich the soil, and afford food for vegetation. How is it, then, that agriculture, which cannot increase the quantity of those elements that are required to manure the earth, can increase its produce so wonderfully as is found to be the case in all cultivated countries?

Mrs. B. It is by suffering none of these decaying bodies to be dissipated, but in applying them duly to the soil. It is by a judicious preparation of the soil, which consists in fitting it either for the general purposes of vegetation, or for that of the particular seed which is to be sown. Thus, if the soil be too wet, it may be drained; if too loose and sandy, it may be rendered more consistent and retentive of water by the addition of clay or loam; it may be enriched by chalk, or any kind of calcareous earth. On soils thus improved, manures will act with double efficacy, and if attention be paid to spread them on the ground at a proper season of the year, to mix them with the soil so that they may be generally diffused through it, to destroy the weeds which might appropriate these nutritive principles to their own use, to remove the stones which would impede the growth of the plant, &c. we may obtain a produce an hundred fold more abundant than the earth would spontaneously supply.

Emily. We have a very striking instance of this in the scanty produce of uncultivated commons, compared to the rich crops of meadows which are occasionally manured.

Caroline. But, Mrs. B., though experience daily proves the advantage of cultivation, there is still a difficulty which I cannot get over. A certan quantity of elementary principles exist, in nature, which it is not in the power of man either to augment or diminish. Of these principles you have taught us that both the animal and vegetable creation are composed. Now the more of them is taken up by the vegetable kingdom, the less, it would seem, will remain for animals; and, therefore, the more populous the earth becomes, the less it will produce.

Mrs. B. Your reasoning is very plausible; but experience every where contradicts the inference you would draw from it; for we find that the animal and vegetable kingdoms, instead of thriving, as you would suppose, at each other's expense, always increase and multiply together. For you should recollect that animals can derive the elements of which they are formed only through the medium of vegetables. And you must allow that your conclusion would be valid only if every particle of the several principles that could possibly be spared from other purposes were employed in the animal and vegetable creations. Now we have reason to believe that a much greater proportion of these principles than is required for such pusposes remains either in an elementary state, or engaged in a less useful mode of combination in the mineral kingdom. Possessed of such immense resources as the atmosphere and the waters afford us, for oxygen, hydrogen, and carbon, so far from being in danger of working up all our simple materials, we cannot suppose that we shall ever bring agriculture to such a degree of perfection as to require the whole of what these resources could supply.

Nature, however, in thus furnishing us with an inexhaustible stock of raw materials, leaves it in some measure to the ingenuity of man to appropriate them to its own purposes. But like a kind parent, she stimulates him to exertion, by setting the example and pointing out the way. For it is on the operations of nature that all the improvements of art are founded. The art of agriculture consists, therefore, in discovering the readiest method of obtaining the several principles, either from their grand sources, air and water, or from the decomposition of organised bodies; and in appropriating them in the best manner to the purposes of vegetation.

Emily. But, among the sources of nutritive principles, I am surprised that you do not mention the earth itself, as it contains abundance of coals, which are chiefly composed of carbon.

Mrs. B. Though coals abound in carbon, they cannot, on account of their hardness and impermeable texture, be immediately subservient to the purposes of vegetation.

Emily. No; but by their combustion carbonic acid is produced; and this entering into various combinations on the surface of the earth, may, perhaps, assist in promoting vegetation.

Mrs. B. Probably it may in some degree; but at any rate the quantity of nourishment which vegetables derive from that source can be but very trifling, and must entirely depend on local circumstances.

Caroline. Perhaps the smoky atmosphere of London is the cause of vegetation being so forward and so rich in its vicinity?

Mrs. B. I rather believe that this circumstance proceeds from the very ample supply of manure, assisted, perhaps, by the warmth and shelter which the town affords. Far from attributing any good to the smoky atmosphere of London, I confess I like to anticipate the time when we shall have made such progress in the art of managing combustion, that every particle of carbon will be consumed, and the smoke destroyed at the moment of its production. We may then expect to have the satisfaction of seeing the atmosphere of London as clear as that of the country.—But to return to our subject: I hope that you are now convinced that we shall not easily experience a deficiency of nutritive elements to fertilize the earth, and that, provided we are but industrious in applying them to the best advantage by improving the art of agriculture, no limits can be assigned to the fruits that we may expect to reap from our labours.

Caroline. Yes; I am perfectly satisfied in that respect, and I can assure you that I feel already much more interested in the progress and improvement of agriculture.

Emily. I have frequently thought that the culture of the land was not considered as a concern of sufficient importance. Manufactures always take the lead; and health and innocence are frequently sacrificed to the prospect of a more profitable employment. It has often grieved me to see the poor manufacturers crowded together in close rooms, and confined for the whole day to the most uniform and sedentary employment, instead of being engaged in that innocent and salutary kind of labour, which Nature seems to have assigned to man for the immediate acquirement of comfort, and for the preservation of his existence. I am sure that you agree with me in thinking so, Mrs. B.?

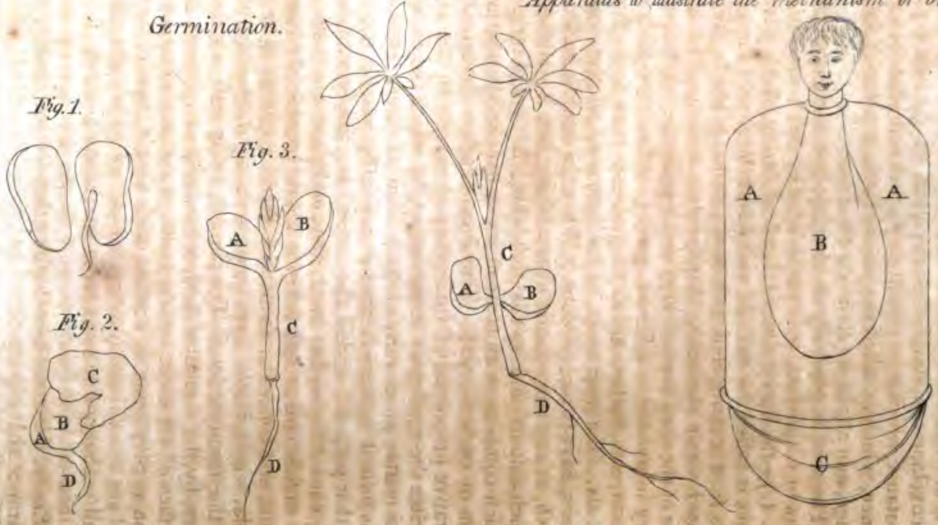
Mrs. B. I am entirely of your opinion, my dear, in regard to the importance of agriculture; but as the conveniences of life, which we are all enjoying, are not derived merely from the soil, I am far from wishing to depreciate manufactures. Besides, as the labour of one man is sufficient to produce food for several, those whose industry is not required in tillage must do something in return for the food that is provided for them. They exchange, consequently, the accommodations for the necessaries of life. Thus the carpenter and the weaver lodge and clothe the peasant, who supplies them with their daily bread. The greater stock of provisions, therefore, which the husbandman produces, the greater is the quantity of accommodation which the artificer prepares. Such are the happy effects which naturally result from civilized society. It would be wiser, therefore, to endeavour to improve the situation of those who are engaged in manufactures, than to indulge in vain declamations on the hardships to which they are too frequently exposed.

But we must not yet take our leave of the subject of agriculture; we have prepared the soil, it remains for us now to sow the seed. In this operation we must be careful not to bury it too deep in the ground, as the access of air is absolutely necessary to its germination; the earth must, therefore, lie loose and light over it, in order that the air may penetrate. Hence the use of ploughing and digging, harrowing and raking, &c. A certain degree of heat and moisture, such as usually takes place in the spring, is likewise necessary.

Caroline. One would imagine you were going to describe the decomposition of an old plant, rather than the formation of a new one; for you have enumerated all the requisites of fermentation.

Mrs. B. Do you forget, my dear, that the young plant derives its existence from the destruction of the seed, and that it is actually by the saccharine fermentation that the latter is decomposed?

Caroline. True; I wonder that I did not recollect that. The temperature and moisture required for the germination of the seed is then employed in producing the saccharine fermentation within it?



Germination.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Apparatus to illustrate the mechanism of breathing.

Fig. 1. & 2. A.B. Cotyledons.—C Envelope.—D Radicle.—Fig. 3. A.B Cotyledons.—C Plumula.—D Radicle.—Fig. 4. A.B Cotyledons.—C Plumula.—D Radicle.
Fig. 5. A.A. Glass bell.—B Bladder representing the lungs.—C Bladder representing the Diaphragm.

Mrs. B. Certainly. But, in order to understand the nature of germination, you should be acquainted with the different parts of which the seed is composed. The external covering or envelope contains, beside the germ of the future plant, the substance which is to constitute its first nourishment; this substance, which is called the *parenchyma*, consists of fecula, mucilage, and oil, as we formerly observed.

The seed is generally divided into two compartments, called *lobes* or *cotyledons*, as is exemplified by this bean (PLATE XV. fig. 1.)—the dark-coloured kind of string which divides the lobes is called the *radicle*, as it forms the root of the plant, and it is from a contiguous substance, called *plumula*, which is inclosed within the lobes, that the stem arises. The figure and size of the seed depend very much upon the cotyledons; these vary in number in different seeds; some have only one, as wheat, oats, barley, and all the grasses; some have three, others six. But most seeds, as for instance, all the varieties of beans, have two cotyledons. When the seed is buried in the earth, at any temperature above 40 degrees, it imbibes water, which softens and swells the lobes; it then absorbs oxygen, which combines with some of its carbon, and is returned in the form of carbonic acid. This loss of carbon increases the comparative proportion of hydrogen and oxygen in the seed, and excites the saccharine fermentation, by which the parenchymatous matter is converted into a kind of sweet emulsion. In this form it is carried into the radicle by vessels appropriated to that purpose; and in the mean time, the fermentation having caused the seed to burst, the cotyledons are rent asunder, the radicle strikes into the ground and becomes the root of the plant, and hence the fermented liquid is conveyed to the plumula, whose vessels have been previously distended by the heat of the fermentation. The plumula being thus swelled, as it were, by the emulative fluid, raises itself and springs up to the surface of the earth, bearing with it the cotyledons, which, as soon as they come in contact with the air, spread themselves, and are transformed into leaves.—If we go into the garden, we shall probably find some seeds in the state which I have described—

Emily. Here are some lupines that are just making their appearance above ground.

Mrs. B. We shall take up several of them to observe their different degrees of progress in vegetation. Here is one that has but recently burst its envelope—do you see the little radicle striking downwards? (PLATE XV. fig. 2.) In this the plumula is not yet visible. But here is another in a greater state of forwardness—the plumula, or stem, has risen out of the ground, and the cotyledons are converted into seeds leaves. (PLATE XV. fig. 3.)

Caroline. These leaves are very thick and clumsy; and unlike the other leaves, which I perceive are just beginning to appear.

Mrs. B. It is because they retain the remains of the parenchyma, with which they still continue to nourish the young plant, as it has not yet sufficient roots and strength to provide for its sustenance from the soil.—But, in this third lupine (PLATE XIV. fig. 4.,) the radicle had sunk deep into the earth, and sent out several shoots, each of which is furnished with a mouth to suck up nourishment from the soil; the function of the original leaves, therefore, being no longer required, they are gradually decaying, and the plumula is become a regular stem, shooting out small branches, and spreading its foliage.

Emily. There seems to be a very striking analogy between a seed and an egg; both require an elevation of temperature to be brought to life; both at first supply with aliment the organised being which they produce; and as soon as this has attained sufficient strength to procure its own nourishment, the egg-shell breaks, whilst in the plant the seed-leaves fall off.

Mrs. B. There is certainly some resemblance between these processes; and when you become acquainted with animal chemistry, you will frequently be struck with its analogy to that of the vegetable kingdom.

As soon as the young plant feeds from the soil, it requires the assistance of leaves, which are the organs by which it throws off its super-abundant fluid; this secretion is much more plentiful in the vegetable than in the animal creation, and the great extent of surface of the foliage of plants is admirably calculated for carrying it on in sufficient quantities. This transpired fluid consists of little more than water. The sap, by this process, is converted into a liquid of greater consistence, which is fit to be assimilated to its several parts.

Emily. Vegetation, then, must be essentially injured by destroying the leaves of the plant?

Mrs. B. Undoubtedly; it not only diminishes the transpiration, but also the absorption by the roots; for the quantity of sap absorbed is always in proportion to the quantity of fluid thrown off by transpiration. You see, therefore, the necessity that a young plant should unfold its leaves as soon as it begins to derive its nourishment from the soil; and, accordingly, you will find that those lupines which have dropped their seed-leaves, and are no longer fed by the parenchyma, have spread their foliage, in order to perform the office just described.

But I should inform you that this function of transpiration seems to be confined to the upper surface of the leaves, whilst, on the contrary, the lower surface, which is more rough and uneven, and furnished with a kind of hair or down, is destined to absorb moisture, or such other ingredients as the plant derives from the atmosphere.

As soon as a young plant makes its appearance above ground, light, as well as air, becomes necessary to its preservation. Light is essential to the developement of the colours, and to the thriving of the plant. You may have often observed what a predilection vegetables have for the light. If you make any plants grow in a room, they all spread their leaves, and extend their branches towards the windows.

Caroline. And many plants close up their flowers as soon as it is dark.

Emily. But may not this be owing to the cold and dampness of the evening air?

Mrs. B. That does not appear to be the case; for in a course of curious experiments, made by Mr. Senebier of Geneva, on plants which he reared by lamp-light, he found that the flowers closed their petals whenever the lamps were extinguished.

Emily. But pray why is air essential to vegetation, plants do not breathe it like animals?

Mrs. B. At least not in the same manner; but they certainly derive some principles from the atmosphere, and yield others to it. Indeed it is chiefly owing to the action of the atmosphere and the vegetable kingdom on each other, that the air continues always fit for respiration. But you will understand this better when I have explained the effect of water on plants.

I have said that water forms the chief nourishment of plants; it is the basis not only of the sap, but of all the vegetable juices. Water is the vehicle which carries into the plant the various salts and other ingredients required for the formation and support of the vegetable system. Nor is this all; part of the water itself is decomposed by the organs of the plant; the hydrogen becomes a constituent part of oil, of extract, of colouring matter, &c. whilst a portion of the oxygen enters into the formation of mucilage, of fecula, of sugar, and of vegetable acids. But the greater part of the oxygen, proceeding from the decomposition of the water, is converted into a gaseous state by the caloric disengaged from the hydrogen during its condensation in the formation of the vegetable materials. In this state the oxygen is transpired by the leaves of plants when exposed to the sun's rays. Thus you find that the decomposition of water, by the organs of the plant, is not only a means of supplying it with its chief ingredient, hydrogen, but at the same time of replenishing the atmosphere with oxygen, a principle which requires continual renovation, to make up for the great consumption of it occasioned by the numerous oxygenations, combustions, and respirations, that are constantly taking place on the surface of the globe.*

Emily. What a striking instance of the harmony of nature.

Mrs. B. And how admirable the design of Providence, who makes every different part of the creation thus contribute to the support and renovation of each other!

But the intercourse of the vegetable and animal kingdoms through the medium of the atmosphere extends still further. Animals, in breathing, not only consume the oxygen of the air, but load it with carbonic acid, which, if accumulated in the atmosphere, would, in a short time, render it totally unfit for respiration. Here the vegetable kingdom again interferes; it attracts and decomposes the carbonic acid, retains the carbon for its own purposes, and returns the oxygen for ours.†

Caroline. How interesting this is! I do not know a more beautiful illustration of the wisdom which is displayed in the laws of nature.

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* The foregoing paragraph might mislead the student. Indeed it seems to have been written without regard to proper authorities. For instance, there is no proof that water is decomposed by the organs of plants; nor is it in the least degree probable that the oxygen emitted by them owes its gaseous state, to the caloric set free by the condensation of hydrogen. Authors on this subject agree that the thickest veil covers the processes by which the sap is converted into the several parts of the plant. But it has been demonstrated, that most, if not all the oxygen emitted by the leaves, is obtained by the decomposition of air, instead of water, as here stated. If leaves are exposed to the rays of the sun, while under common water, they emit oxygen. But if the water is first deprived of its air, by an air pump, or by boiling, not a particle of oxygen is emitted. Now atmospheric air, always contains a quantity of carbonic acid gas, and experiments show, that plants give out oxygen in some proportion to the quantity of this gas contained in the water. The fact then seems to be, that plants absorb carbonic acid, that this is decomposed by some unknown process; the plant retaining the carbon while the oxygen is given out. C.

† It is a curious fact, demonstrated by experiments, that the leaves of plants perform different offices at different periods of the 24 hours. During the day they give out water, absorb carbonic acid, and emit oxygen gas; but during the night they absorb water, and oxygen gas, and give out carbonic acid. C.

Mrs. B. Faint and imperfect as are the ideas which our limited perceptions enable us to form of divine wisdom, still they cannot fail to inspire us with awe and admiration. What, then, would be our feelings, were the complete system of nature at once displayed before us! So magnificent a scene would probably be too great for our limited and imperfect comprehension, and it is no doubt among the wise dispensations of Providence, to veil the splendour of a glory with which we should be overpowered. But it is well suited to the nature of a rational being to explore, step by step, the works of the creation, to endeavour to connect them into harmonious systems; and, in a word, to trace in the chain of beings, the kindred ties and benevolent design which unites its various links, and secures its preservation.

Caroline. But of what nature are the organs of plants which are endued with such wonderful powers?

Mrs. B. They are so minute that their structure, as well as the mode in which they perform their functions, generally elude our examination; but we may consider them as so many vessels or apparatus appropriated to perform, with the assistance of the principle of life, certain chemical processes, by means of which these vegetable compounds are generated. We may, however, trace the tannin, resins, gum, mucilage, and some other vegetable materials, in the organised arrangement of plants, in which they form the bark, the wood, the leaves, flowers, and seeds.

The *bark* is composed of the *epidermis*, the *parenchyma*, and the *cortical layers.*

The epidermis is the external covering of the plant. It is a thin transparent membrane, consisting of a number of slender fibres, crossing each other, and forming a kind of net-work. When of a white glossy nature, as in several species of trees, in the stems of corn and of seeds, it is composed of a thin coating of siliceous earth, which accounts for the strength and hardness of those long and slender stems. Sir H. Davy was led to the discovery of the siliceous nature of the epidermis of such plants, by observing the singular phenomenon of sparks of fire emitted by the collision of ratan canes with which two boys were fighting in a dark room. On analysing the epidermis of the cane, he found it to be almost entirely siliceous.*

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* In the scouring rush, (*Equisetum hyemale*) the siliceous epidermis is still more obvious. If drawn across a piece of soft metal, as

Caroline. With iron then, a cane, I suppose, will strike fire very easily?

Mrs. B. I understand that it will.—In ever-greens the epidermis is mostly resinous, and in some few plants is formed of wax. The resin, from its want of affinity for water, tends to preserve the plant from the destructive effects of violent rains, severe climates, or inclement seasons, to which this species of vegetables is peculiarly exposed.

Emily. Resin must preserve wood just like a varnish, as it is the essential ingredient of varnishes?

Mrs. B. Yes; and by this means it prevents likewise all unnecessary expenditure of moisture.

The parenchyma is immediately beneath the epidermis; it is that green rind which appears when you strip a branch of any tree or shrub of its external coat of bark. The parenchyma is not confined to the stem or branches, but extends over every part of the plant. It forms the green matter of the leaves, and is composed of tubes filled with a peculiar juice.

The cortical layers are immediately in contact with the wood; they abound with tannin and gallic acid, and consist of small vessels through which the sap descends after being elaborated in the leaves. The cortical layers are annually renewed, the old bark being converted into wood.

Emily. But through what vessels does the sap ascend?

Mrs. B. That function is performed by the tubes of the alburnum, or wood, which is immediately beneath the cortical layers. The wood is composed of woody fibre, mucilage, and resin. The fibres are disposed in two ways; some of them longitudinally, and these form what is called the silver grain of the wood. The others, which are concentric, are called the spurious grain. These last are disposed in layers, from the number of which the age of the tree may be computed, a new one being produced annually by the conversion of the bark into wood. The oldest, and consequently most internal part of the alburnum, is called heart-wood; it appears to be dead, at least no vital functions are discernible in it. It is through the tubes of the living alburnum that the sap rises. These, therefore, spread into the leaves, and there communicate with the extremities of the vessels of the cortical layers, into which they pour their contents.

Caroline. Of what use, then, are the tubes of the parenchy-

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silver or copper, it cuts it like a file. It even makes an impression on the hardest steel. C.

ma, since neither the ascending nor descending sap passes through them?

Mrs. B. They are supposed to perform the important function of secreting from the sap the peculiar juices from which the plant more immediately derives its nourishment. These juices are very conspicuous, as the vessels which contain them are much larger than those through which the sap circulates. The peculiar juices of plants differ much in their nature, not only in different species of vegetables, but frequently in different parts of the same individual plant: they are sometimes saccharine, as in the sugar-cane, sometimes resinous, as in firs and evergreens, sometimes of a milky appearance, as in the laurel.

Emily. I have often observed, that in breaking a young shoot, or in bruising a leaf of laurel, a milky juice will ooze out in great abundance.

Mrs. B. And it is by making incisions in the bark that pitch, tar, and turpentine* are obtained from fir-trees. The durability of this species of wood is chiefly owing to the resinous nature of its peculiar juices. The volatile oils have, in a great measure the same preservative effects, as they defend the parts, with which they are connected, from the attack of insects. This tribe seems to have as great an aversion to perfumes, as the human species have delight in them. They scarcely ever attack any odoriferous parts of plants, and it is not uncommon to see every leaf of a tree destroyed by a blight, whilst the blossoms remain untouched. Cedar, sandal, and all aromatic woods, are on this account of great durability.

Emily. But the wood of the oak, which is so much esteemed for its durability, has, I believe, no smell. Does it derive this quality from its hardness alone?

Mrs. B. Not entirely; for the chesnut, though considerably harder and firmer than the oak, is not so lasting. The durability of the oak is, I believe, in a great measure owing to its having very little heart-wood, the alburnum preserving its vital functions longer than in other trees.

Caroline. If incisions are made into the alburnum and cortical layers, may not the ascending and descending sap be procured in the same manner as the peculiar juice is from the vessels of the parenchyma?

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* Turpentine is obtained as described in the text. But tar and pitch are obtained by a very different method. A conical cavity is dug in the earth, at the bottom of which is placed a reservoir. Over this is piled billets of fir-wood, forming a large pile. The pile is covered with turf to smother the fire, which is kindled at the top. As the wood is heated, and gradually converted into charcoal, the tar is driven out, and runs into the cavity, and finally into the reservoir. Tar is a mixture of *resin*, *empyreumatis oil*, *charcoal*, and *acetic* acid. The colour is derived from the charcoal. *Pitch* is made by boiling tar, by which its more volatile parts are driven off. C.

Mrs. B. Yes; but in order to obtain specimens of these fluids, in any quantity, the experiment must be made in the spring, when the sap circulates with the greatest energy. For this purpose a small bent glass tube should be introduced into the incision, through which the sap may flow without mixing with any of the other juices of the tree. From the bark the sap will flow much more plentifully than from the wood, as the ascending sap is much more liquid, more abundant, and more rapid in its motion than that which descends; for the latter having been deprived by the operation of the leaves of a considerable part of its moisture, contains a much greater proportion of solid matter, which retards its motion. It does not appear that there is any excess of descending sap, as none ever exudes from the roots of plants; this process, therefore, seems to be carried on only in proportion to the wants of the plant, and the sap descends no further, and in no greater quantity, than is required to nourish the several organs. Therefore, though the sap rises and descends in the plant, it does not appear to undergo a real circulation.

The last of the organs of plants is the *flower*, or *blossom*, which produces the *fruits* and *seed*. These may be considered as the ultimate purpose of nature in the vegetable creation. From fruits and seeds animals derive both a plentiful source of immediate nourishment, and an ample provision for the reproduction of the same means of subsistence.

The seed which forms the final product of mature plants, we have already examined as constituting the first rudiments of future vegetation.

These are the principal organs of vegetation, by means of which the several chemical processes which are carried on during the life of the plant are performed.

Emily. But how are the several principles which enter into the composition of vegetables so combined by the organs of the plant as to be converted into vegetable matter?

Mrs. B. By chemical processes, no doubt; but the apparatus in which they are performed is so extremely minute as to elude our examination. We can form an opinion, therefore, only by the result of these operations. The sap is evidently composed of water, absorbed by the roots, and holding in solution the various principles which it derives from the soil. From the roots the sap ascends through the tubes of the alburnum into the stem, and thence branches out to every extremity of the plant. Together with the sap circulates a certain quantity of carbonic acid, which is gradually disengaged from the former by the internal heat of the plant.

Caroline. What? have vegetables a peculiar heat, analogous to animal heat?

Mrs. B. It is a circumstance that has long been suspected; but late experiments have decided beyond a doubt, that vegetable heat is considerably above that of unorganised matter in winter, and below it in summer. The wood of a tree is about sixty degrees, when the thermometer is seventy or eighty degrees. And the bark, though so much exposed, is seldom below forty in winter.

It is from the sap, after it has been elaborated by the leaves, that vegetables derive their nourishment; in its progress through the plant from the leaves to the roots, it deposits in the several sets of vessels with which it communicates, the materials on which the growth and nourishment of each plant depends. It is thus that the various peculiar juices, saccharine, oily, mucous, acid, and colouring, are formed; as also the more solid parts, fecula, woody fibre, tannin, resins, concrete salts: in a word, all the immediate materials of vegetables, as well as the organised parts of plants, which latter, besides the power of secreting these from the sap for the general purpose of the plant, have also that of applying them to their own particular nourishment.

Emily. But why should the process of vegetation take place only at one season of the year, whilst a total inaction prevails during the other?

Mrs. B. Heat is such an important chemical agent, that its effect, as such, might perhaps alone account for the impulse which the spring gives to vegetation. But, in order to explain the mechanism of that operation, it has been supposed that the warmth of the spring dilates the vessels of plants, and produces a kind of vacuum, into which the sap (which had remained in a state of inaction in the trunk during the winter) rises; this is followed by the ascent of the sap contained in the roots, and room is thus made for fresh sap, which the roots, in their turn, pump up from the soil. This process goes on till the plant blossoms and bears fruit, which terminates its summer career: but when the cold weather sets in, the fibres and vessels contract, the leaves wither, and are no longer able to perform their office of transpiration; and as this secretion stops, the roots cease to absorb sap from the soil. If the plant be an annual, its life then terminates; if not, it remains in a state of torpid inaction during the winter; or the only internal motion that takes place is that of a small quantity of resinous juice, which slowly rises from the stem into the branches, and enlarges their buds during the winter.

Caroline. Yet, in evergreens, vegetation must continue throughout the year.

Mrs. B. Yes; but in winter it goes on in a very imperfect manner, compared to the vegetation of spring and summer.

We have dwelt much longer on the history of vegetable chemistry than I had intended; but we have at length I think, brought the subject to a conclusion.

Caroline. I rather wonder that you did not reserve the account of the fermentations for the conclusion; for the decomposition of vegetables naturally follows their death, and can hardly, it seems, be introduced with so much propriety at any other period.

Mrs. B. It is difficult to determine at what point precisely it may be most eligible to enter on the history of vegetation; every part of the subject is so closely connected, and forms such an uninterrupted chain, that it is by no means easy to divide it. Had I begun with the germination of the seed, which, at first view, seems to be the most proper arrangement, I could not have explained the nature and fermentation of the seed, or have described the changes which manure must undergo, in order to yield the vegetable elements. To understand the nature of germination, it is necessary, I think, previously to decompose the parent plant, in order to become acquainted with the materials required for that purpose. I hope, therefore, that, upon second consideration, you will find that the order which I have adopted, though apparently less correct, is in fact the best calculated for the elucidation of the subject.

CONVERSATION XXIII.

ON THE COMPOSITION OF ANIMALS.

Mrs. B. We are now come to the last branch of chemistry, which comprehends the most complicated order of compound beings. This is the animal creation, the history of which cannot but excite the highest degree of curiosity and interest, though we often fail in attempting to explain the laws by which it is governed.

Emily. But since all animals ultimately derive their nourishment from vegetables, the chemistry of this order of beings must consist merely in the conversion of vegetable into animal matter.

Mrs. B. Very true; but the manner in which this is effected is, in a great measure, concealed from our observation. This process is called *animalisation*, and is performed by peculiar organs. The difference of the animal and vegetable kingdoms does not however depend merely on a different arrangement of combinations. A new principle abounds in the animal kingdom, which is but rarely and in very small quantities found in vegetables; this is nitrogen. There is likewise in animal substances a greater and more constant proportion of phosphoric acid, and other saline matters. But these are not essential to the formation of animal matter.

Caroline. Animal compounds contain, then, four fundamental principles; oxygen, hydrogen, carbon, and nitrogen?

Mrs. B. Yes; and these form the immediate materials of animals, which are *gelatin*, *albumen*, and *fibrine*.*

Emily. Are those all? I am surprised that animals should be composed of fewer kinds of materials than vegetables; for they appear much more complicated in their organisation.

Mrs. B. Their organisation is certainly more perfect and intricate, and the ingredients that occasionally enter into their composition are more numerous. But notwithstanding the wonderful variety observable in the texture of the animal organs, we find that the original compounds, from which all the varieties of animal matter are derived, may be reduced to the three heads just mentioned. Animal substances being the most complicated of all natural compounds, are most easily susceptible of decomposition, as the scale of attractions increases in proportion to the number of constituent principles. Their analysis is, however, both difficult and imperfect; for as they cannot be examined in their living state, and are liable to alteration immediately after death, it is probable that, when submtted to the investigation of a chemist, they are always more or less altered in their combinations and properties, from what they were, whilst they made part of the living animal.

Emily. The mere diminution of temperature, which they experience by the privation of animal heat, must, I should suppose, be sufficient to derange the order of attractions that existed during life.

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* These are the principal ingredients of the soft parts. But in addition to these, animal substances contain, *colouring matter of blood*, *mucous*, *sulphur*, *phosphorus*, *earths*, *alkalies*, *oils*, *acids*, *resins*, and several others, which it is unnecessary to specify. C

Mrs. B. That is one of the causes, no doubt: but there are many other circumstances which prevent us from studying the nature of living animal substances. We must therefore, in a considerable degree, confine our researches to the phenomena of these compounds in their inanimate state.

These three kinds of animal matter, gelatine, albumen, and fibrine, form the basis of all the various parts of the animal system; either solid, as the *skin*, *flesh*, *nerves*, *membranes*, *cartilages*, and *bones*; or fluid, as *blood*, *chyle*, *milk*, *mucus*, the *gastric* and *pancreatic juices*, *bile*, *perspiration*, *saliva*, *tears*, &c.

Caroline. Is it not surprising that so great a variety of substances, and so different in their nature, should yet all arise from so few materials, and from the same original elements?

Mrs. B. The difference in the nature of various bodies depends, as I have often observed to you, rather on their state of combination, than on the materials of which they are composed. Thus, in considering the chemical nature of the creation in a general point of view, we observe that it is throughout composed of a very small number of elements. But when we divide it into the three kingdoms, we find that, in the mineral, the combinations seem to result from the union of elements casually brought together; whilst in the vegetable and and animal kingdoms, the attractions are peculiarly and regularly produced by appropriate organs, whose action depends on the vital principle. And we may further observe, that by means of certain spontaneous changes and decompositions, the elements of one kind of matter become subservient to the reproduction of another; so that the three kingdoms are intimately connected, and constantly contributing to the preservation of each other.

Emily. There is, however, one very considerable class of elements, which seems to be confined to the mineral kingdom: I mean metals.

Mrs. B. Not entirely; they are found, though in very minute quantities, both in the vegetable and animal kingdoms. A small portion of earths and sulphur enters also into the composition of organised bodies. Phosphorus, however, is almost entirely confined to the animal kingdom; and nitrogen, but with few exceptions, is extremely scarce in vegetables.

Let us now proceed to examine the nature of the three principal materials of the animal system.

Gelatine, or *jelly*, is the chief ingredient of skin, and of all the membranous parts of animals. It may be obtained from these substances, by means of boiling water under the forms of glue, size, isinglass, and transparent jelly.

Caroline. But these are of a very different nature; they cannot therefore be all pure gelatine.

Mrs. B. Not entirely, but very nearly so. Glue* is extracted from the skin of animals. Size is obtained either from skin in its natural state, or from leather. Isinglass is gelatine procured from a particular species of fish; it is, you know, of this substance that the finest jelly is made, and this is done by merely dissolving the isinglass in boiling water, and allowing the solution to congeal.

Emily. The wine, lemon, and spices, are, I suppose, added only to flavour the jelly?

Mrs. B. Exactly so.

Caroline. But jelly is often made of hartshorn shavings, and of calves' feet; do these substances contain gelatine?

Mrs. B. Yes. Gelatine may be obtained from almost any animal substance, as it enters more or less into the composition of all of them. The process for obtaining it is extremely simple, as it consists merely in boiling the substance which contains it, with water. The gelatine dissolves in water, and may be attained of any degree of consistence or strength, by evaporating this solution. Bones in particular produce it very plentifully, as they consist of phosphat of lime combined or cemented by gelatine. Horns, which are a species of bone, will yield abundance of gelatine. The horns of the hart are reckoned to produce gelatine of the finest quality; they are reduced to the state of shavings in order that the jelly may be more easily extracted by the water. It is of hartshorn shavings that the jellies for invalids are usually made, as they are of very easy digestion.

Caroline. It appears singular that hartshorn, which yields such a powerful ingredient as ammonia, should at the same time produce so mild and insipid a substance as jelly?

Mrs. B. And (what is more surprising) it is from the gelatine of bones that ammonia is produced. You must observe, however, that the processes by which these two substances are obtained from bones are very different. By the simple action of water and heat, the gelatine is separated; but in order to procure the ammonia, or what is commonly called hartshorn, the bones must be distilled, by which means the gelatine is decomposed, and hydrogen and nitrogen combined in the form of ammonia. So that the first operation is a mere separation of ingredients, whilst the second requires a chemical decomposition.

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* Bones, muscles, tendons, ligaments, membranes, and skins, all of them yield glue. But the best is made from the skins of old animals. C.

Caroline. But when jelly is made from hartshorn shavings, what becomes of the phosphat of lime which constitutes the other part of bones?

Mrs. B. It is easily separated by straining. But the jelly is afterwards more perfectly purified, and rendered transparent, by adding white of egg, which being coagulated by heat, rises to the surface along with any impurities.

Emily. I wonder that bones are not used by the common people to make jelly; a great deal of wholesome nourishment, might, I should suppose, be procured from them, though the jelly would perhaps not be quite so good as if made from hartshorn shavings?

Mrs. B. There is a prejudice among the poor against a species of food that is usually thrown to the dogs; and as we cannot expect them to enter into chemical considerations, it is in some degree excusable. Besides it requires a prodigious quantity of fuel to dissolve bones and obtain the gelatine from them.

The solution of bones in water is greatly promoted by an accumulation of heat. This may be effected by means of an extremely strong metallic vessel, called *Papin's digester*, in which the bones and water are enclosed, without any possibility of the steam making its escape. A heat can thus be applied much superior to that of boiling water; and bones, by this means, are completely reduced to a pulp. But the process still consumes too much fuel to be generally adopted among the lower classes.

Caroline. And why should not a manufacture be established for grinding or macerating bones, or at least for reducing them to the state of shavings, when I suppose they would dissolve as readily as hartshorn shavings?

Mrs. B. They could not be collected clean for such a purpose, but they are not lost, as they are used for making hartshorn and sal ammoniac; and such is the superior science and industry of this country, that we now send sal ammoniac to the Levant, though it originally came to us from Egypt.

Emily. When jelly is made of isinglass, does it leave no sediment?

Mrs. B. No; nor does it so much require clarifying, as it consists almost entirely of pure gelatine, and any foreign matter that is mixed with it, is thrown off during the boiling in the form of scum.—These are processes which you may see performed in great perfection in the culinary laboratory, by that very able and most useful chemist the cook.

Caroline. To what an immense variety of purposes chemistry is subservient!

Emily. It appears, in that respect, to have an advantage over most other arts and sciences; for these, very often, have a tendency to confine the imagination to their own particular object, whilst the pursuit of chemistry is so extensive and diversified, that it inspires a general curiosity, and a desire of enquiring into the nature of every object.

Caroline. I suppose that soup is likewise composed of gelatine; for, when cold, it often assumes the consistence of jelly?

Mrs. B. Not entirely; for though soups generally contain a quantity of gelatine, the most essential ingredient is a mucous or extractive matter, a peculiar animal substance, very soluble in water, which has a strong taste, and is more nourishing than gelatine. The various kinds of portable soup consist of this extractive matter in a dry state, which, in order to be made into soup, requires only to be dissolved in water.

Gelatine, in its solid state, is a semiductile transparent substance, without either taste or smell.—When exposed to heat, in contact with air and water, it first swells, then fuses, and finally burns. You may have seen the first part of this operation performed in the carpenter's glue-pot.

Caroline. But you said that gelatine had no smell, and glue has a very disagreeable one.

Mrs. B. Glue is not pure gelatine; as it is not designed for eating, it is prepared without attending to the state of the ingredients, which are more or less contaminated by particles that have become putrid.

Gelatine may be precipitated from its solution in water by alcohol.—We shall try this experiment with a glass of warm jelly.—You see that the gelatine subsides by the union of the alcohol and the water.

Emily. How is it, then, that jelly is flavoured with wine, without producing any precipitation?

Mrs. B. Because the alcohol contained in wine is already combined with water, and other ingredients, and is therefore not at liberty to act upon the jelly as when in its separate state. Gelatine is soluble both in acids and in alkalies; the former, you know, are frequently used to season jellies.

Caroline. Among the combinations of gelatine we must not forget one which you formerly mentioned; that with tannin, to form leather.

Mrs. B. True; but you must observe that leather can be produced only by gelatine in a membranous state; for though pure gelatine and tannin will produce a substance chemically similar to leather, yet the texture of the skin is requisite to make it answer the useful purposes of that substance.

The next animal substance we are to examine is *albumen*; this, although constituting a part of most of the animal compounds, is frequently found insulated in the animal system; the white of egg, for instance, consists almost entirely of albumen; the substance that composes the nerves, the serum, or white part of the blood, and the curds of milk, are little else than albumen variously modified.

In its most simple state, albumen appears in the form of a transparent viscous fluid, possessed of no distinct taste or smell; it coagulates at the low temperature of 165 degrees, and, when once solidified, it will never return to its fluid state.

Sulphuric acid and alcohol are each of them capable of coagulating albumen in the same manner as heat, as I am going to show you.

Emily. Exactly so.—Pray, Mrs. B., what kind of action is there between albumen and silver? I have sometimes observed, that if the spoon with which I eat an egg happens to be wetted, it becomes tarnished.

Mrs. B. It is because the white of egg (and, indeed, albumen in general) contains a little sulphur, which, at the temperature of an egg just boiled, will decompose the drop of water that wets the spoon, and produce sulphurated hydrogen gas, which has the property of tarnishing silver.

We may now proceed to *fibrine*. This is an insipid and inodorous substance, having somewhat the appearance of fine white threads adhering together; it is the essential constituent of muscles or flesh, in which it is mixed with and softened by gelatine. It is insoluble both in water and alcohol, but sulphuric acid converts it into a substance very analogous to gelatine.

These are the essential and general ingredients of animal matter; but there are other substances, which, though not peculiar to the animal system, usually enter into its composition, such as oils, acids, salts, &c.

Animal oil is the chief constituent of fat; it is contained in abundance in the cream of milk, whence it is obtained in the form of butter.

Emily. Is animal oil the same in its composition as vegetable oils?

Mrs. B. Not the same, but very analogous. The chief difference is that animal oil contains nitrogen, a principle which seldom enters into the composition of vegetable oils, and never in so large a proportion.

There are a few animal acids, that is to say, acids peculiar to animal matter, from which they are almost exclusively obtained.

The animal acids have triple bases of hydrogen, carbon, and nitrogen. Some of them are found native in animal matter; others are produced during its decomposition.

Those that we find ready formed are:

The *bombic acid*, which is obtained from silk-worms.

The *formic acid*, from ants.

The *latic acid*, from the whey of milk.

The *sebacic*, from oil or fat.

Those produced during the decomposition of animal substances by heat, are the *prussic* and *zoonic* acids. This last is produced by the roasting of meat, and gives it a brisk flavour.

Caroline. The class of animal acids is not very extensive?

Mrs. B. No; nor are they, generally speaking, of great importance. The *prussic acid** is, I think, the only one sufficiently interesting to require any further comment. It can be formed by an artificial process without the presence of any animal matter; and it may likewise be obtained from a variety of vegetables, particularly those of the narcotic kind, such as poppies, laurel, &c. But it is commonly obtained from blood, by strongly heating that substance with caustic potash; the alkali attracts the acid from the blood, and forms with it a *prussiat of potash*. From this state of combination the prussic acid can be obtained pure by means of other substances which have the power of separating it from the alkali.

Emily. But if this acid does not exist ready formed in blood, how can the alkali attract it from thence?

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* Prussic acid can be obtained from Prussian blue (*prussiate of iron*) by the following process. Take 4 ounces of prussian blue, pulverize it finely, and mix with it 2 1-2 ounces of red oxide of mercury (*red precipitate*;) boil the mixture with 12 ounces of water in a glass vessel, frequently stiring it with a stick. Filter the solution, which is a *prussiate of mercury*, and is formed by the transfer of the prussic acid, from the iron to the mercury. Put this solution into a retort, and add to it two ounces of clean iron filings and six drachms of sulphuric acid, and distil off two and a half ounces of *prussic acid*. This process requires a good apparatus, and ought not to be undertaken by any one who has not a knowledge of practical chemistry. The fumes during the distilation ought carefully to be avoided as poisonous. Prussic acid has of late been much used in medicine, as a remedy in consumption, hooping cough, &c. C.

Mrs. B. It is the tripple basis only of this acid that exists in the blood; and this is developed and brought to the state of acid, during the combustion. The acid therefore is first formed, and it afterwards combines with the potash.

Emily. Now I comprehend it. But how can the prussic acid be artificially made?

Mrs. B. By passing ammoniacal gas over red-hot charcoal; and hence we learn that the constituents of this acid are hydrogen, nitrogen, and carbon. The two first are derived from the volatile alkali, the last from the combustion of the charcoal.

Caroline. But this does not accord with the system of oxygen being the principle of acidity.

Mrs. B. The colouring matter of prussian blue is called an acid, because it unites with alkalies and metals, and not from any other characteristic properties of acids; perhaps the name is not strictly appropriate. But this circumstance, together with some others of the same kind, has induced several chemists to think that oxygen may not be the exclusive generator of acids. Sir H. Davy, I have already informed you, was led by his experiments on dry acids to suspect that water might be essential to acidity. And it is the opinion of some chemists that acidity may possibly depend rather on the arrangement than on the presence of any particular principles. But we have not yet done with the prussic acid. It has a strong affinity for metallic oxyds, and precipitates the solutions of iron in acids of a blue colour. This is the prussian blue, or prussiat of iron, so much used in the arts, and with which I think you must be acquainted.

Emily. Yes, I am; it is much used in painting, both in oil and in water colours; but it is not reckoned a permanent oil-colour.

Mrs. B. That defect arises, I believe, in general, from its being badly prepared, which is the case when the iron is not so fully oxydated as to form a red oxyd. For a solution of green oxyd of iron (in which the metal is more slightly oxydated,) makes only a pale green, or even a white precipitate, with prussiat of potash; and this gradually changes to blue by being exposed to the air, as I can immediately show you.

Caroline. It already begins to assume a pale blue colour. But how does the air produce this change?

Mrs. B. By oxydating the iron more perfectly. If we pour some nitrous acid on it, the prussian blue colour will be immediately produced, as the acid will yield its oxygen to the precipitate and fully saturate it with this principle, as you shall see.

Caroline. It is very curious to see a colour change so instantaneously.

Mrs. B. Hence you perceive that prussian blue cannot be a permanent colour, unless prepared with red oxyd of iron, since by exposure to the atmosphere it gradually darkens, and in a short time is no longer in harmony with the other colours of the painting.

Caroline. But it can never become darker, by exposure to the atmosphere, than the true prussian blue, in which the oxyd is perfectly saturated?

Mrs. B. Certainly not. But in painting, the artist not reckoning upon partial alterations in his colours, gives his blue tints that particular shade which harmonises with the rest of the picture. If, afterwards, those tints become darker, the harmony of the colouring must necessarily be destroyed.

Caroline. Pray, of what nature is the paint called *carmine*?

Mrs. B. It is an animal colour prepared from *cochineal*, an insect, the infusion of which produces a very beautiful red.*

Caroline. Whilst we are on the subject of colours, I should like to learn what *ivory black* is?

Mrs. B. It is a carbonaceous substance obtained by the combustion of ivory. A more common species of black is obtained from the burning of bone.

Caroline. But during the combustion of ivory or bone, the carbon, I should have imagined, must be converted into carbonic acid gas, instead of this black substance?

Mrs. B. In this, as in most combustions, a considerable part of the carbon is simply volatilised by the heat, and again obtained concrete on cooling. This colour, therefore, may be called the soot produced by the burning of ivory or bone.

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CONVERSATION XXIV.

ON THE ANIMAL ECONOMY.

Mrs. B. WE have now acquired some idea of the various materials which compose the animal system; but if you are curious to know in what manner these substances are formed by the animal organs, from vegetable, as well as from animal substances, it will be necessary to have some previous knowledge of the nature and functions of these organs, without which it is impossible to form any distinct idea of the process of *animalisation* and *nutrition*.

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* Carmine is obtained by precipitating the colouring matter from an infusion of the insect by means of a solution of tin. C.

Caroline. I do not exactly understand the meaning of the word animalisation?

Mrs. B. Animalisation is the process by which the food is *assimilated*, that is to say, converted into animal matter; and nutrition is that by which the food thus assimilated is rendered subservient to the purposes of nourishing and maintaining the animal system.

Emily. This, I am sure, must be the most interesting of all the branches of chemistry!

Caroline. So I think; particularly as I expect that we shall hear something of the nature of respiration, and of the circulation of the blood?

Mrs. B. These functions undoubtedly occupy a most important place in the history of the animal economy.—But I must previously give you a very short account of the principal organs by which the various operations of the animal system are performed. These are:

The *Bones*,
Muscles,
Blood vessels,
Lympathic vessels,
Glands, and
Nerves.

The *bones* are the most solid part of the animal frame, and in a great measure determines its form and dimensions. You recollect, I suppose, what are the ingredients which enter into their composition?

Caroline. Yes; phosphat of lime, cemented by gelatine.

Mrs. B. During the earliest period of animal life, they consist almost entirely of gelatinous membrane having the form of the bones, but of a loose sponzy texture, the cells or cavities of which are destined to be filled with phosphat of lime; it is the gradual acquisition of this salt which gives to the bones their subsequent hardness and durability. Infants first receive it from their mother's milk, and afterwards derive it from all animal and from most vegetable food, especially farinaceous substances, such as wheat-flour, which contain it in sensible quantities. A portion of the phosphat, after the bones of the infant have been sufficiently expanded and solidified, is deposited in the teeth, which consist at first only of a gelatinous membrane or case, fitted for the reception of this salt; and which, after acquiring hardness within the gum, gradually protrude from it.

Caroline. How very curious this is; and how ingeniously nature has first provided for the solidification of such bones as are immediately wanted, and afterwards for the formation of the teeth, which would not only be useless, but detrimental in infancy!

Mrs. B. In quadrupeds the phosphats of lime is deposited likewise in their horns, and the hair or wool with which they are generally clothed.

In birds it serves also to harden the beaks and the quills of their feathers.

When animals are arrived at a state of maturity, and their bones have acquired a sufficient degree of solidity, the phosphat of lime which is taken with the food is seldom assimilated, excepting when the female nourishes her young; it is then all secreted into the milk, as a provision for the tender bones of the nursling.

Emily. So that whatever becomes superfluous to one being, is immediately wanted by another; and the child acquires strength precisely by the species of nourishment which is no longer necessary to mother. Nature is, indeed, an admirable economist!

Caroline. Pray, Mrs. B., does not the disease in the bones of children, called the rickets, proceed from a deficiency of phosphat of lime?

Mrs. B. I have heard that this disease may arise from two causes; it is sometimes occasioned by the growth of the muscles being too rapid in proportion to that of the bones. In this case the weight of the flesh is greater than the bones can support, and presses on them so as to produce a swelling of the joints, which is the great indication of the rickets. The other cause of this disorder is supposed to be an imperfect digestion and assimilation of food, attended with an access of acid, which counteracts the formation of phosphat of lime. In both instances, therefore, care should be taken to alter the child's diet, not merely by increasing the quantity of aliment containing phosphat of lime, but also by avoiding all food that is apt to turn acid on the stomach, and to produce indigestion. But the best preservative against complaints of this kind is, no doubt, good nursing: when a child has plenty of air and exercise, the digestion and assimilation will be properly performed, no acid will be produced to interrupt these functions, and the muscles and bones will grow together in just proportions.

Caroline. I have often heard the rickets attributed to bad nursing, but I never could have guessed what connection there was between exercise and the formation of the bones.

Mrs. B. Exercise is generally beneficial to all the animal functions. If man is destined to labour for his subsistence, the bread which he earns is scarcely more essential to his health and preservation, than the exertions by which he obtains it. Those whom the gifts of fortune have placed above the necessity of bodily labour, are compelled to take exercise in some mode or other, and when they cannot convert it into an amusement, they must submit to it as a task, or their health will soon experience the effects of their indolence.

Emily. That will never be my case: for exercise, unless it becomes fatigue, always gives me pleasure; and, so far from being a task, is to me a source of daily enjoyment. I often think what a blessing it is, that exercise, which is so conducive to health, should be so delightful; whilst fatigue, which is rather hurtful, instead of pleasure, occasions painful sensations. So that fatigue, no doubt, was intended to moderate our bodily exertions, as satiety puts a limit to our appetites.

Mrs. B. Certainly.—But let us not deviate too far from our subject.—The bones are connected together by ligaments, which consist of a white thick flexible substance, adhering to their extremities, so far as to secure the joints firmly, though without impeding their motion. And the joints are moreover covered by a solid, smooth, elastic, white substance, called *cartilage*, the use of which is to allow, by its smoothness and elasticity, the bones to slide easily over one another, so that the joints may perform their office without difficulty or detriment.

Over the bones the *muscles* are placed; they consist of bundles of fibres which terminate in a kind of string, or ligament, by which they are fastened to the bones. The muscles are the organs of motion; by their power of dilatation and contraction, they put into action the bones, which act as levers, in all the motions of the body, and form the solid support of its various parts. The muscles are of various degrees of strength or consistence in different species of animals. The mammiferous tribe, or those that suckle their young, seem in this respect to occupy an intermediate place between birds and cold-blooded animals, such as reptiles and fishes.

Emily. The different degrees of firmness and solidity in the muscles of these several species of animals proceed, I imagine, from the different nature of the food on which they subsist?

Mrs. B. No; that is not supposed to be the case: for the human species, who are of the mammiferous tribe, live on more substantial food than birds, and yet the latter exceed them in muscular strength. We shall hereafter attempt to account for this difference; but let us now proceed in the examination of the animal functions.

The next class of organs is that of the *vessels* of the body, the office of which is to convey the various fluids throughout the frame. These vessels are innumerable. The most considerable of them are those through which the blood circulates, which are of two kinds: the *arteries*, which convey it from the heart to the extremities of the body, and the *veins*, which bring it back into the heart.

Besides these, there are a numerous set of small transparent vessels, destined to absorb and convey different fluids into the blood; they are generally called the *absorbent* or *lymphatic* vessels: but it is to a portion of them only that the function of conveying into the blood the fluid called *lymph* is assigned.

Emily. Pray what is the nature of that fluid?

Mrs. B. The nature and use of the lymph have, I believe, never been perfectly ascertained; but it is supposed to consist of matter that has been previously animalised, and which, after answering the purpose for which it was intended, must, in regular rotation, make way for the fresh supplies produced by nourishment. The lymphatic vessels pump up this fluid from every part of the system, and convey it into the veins to be mixed with the blood which runs through them, and which is commonly called venous blood.

Caroline. But does it not again enter into the animal system through that channel?

Mrs. B. Not entirely; for the venous blood does not return into the circulation until it has undergone a peculiar change, in which it throws off whatever is become useless.

Another set of absorbent vessels pump up the *chyle* from the stomach and intestines, and convey it, after many circumvolutions, into the great vein near the heart.*

Emily. Pray what is chyle?

Mrs. B. It is the substance into which food is converted by digestion.

Caroline. One set of the absorbent vessels, then, is employed in bringing away the old materials which are no longer fit for use; whilst the other set is busy in conveying into the blood the new materials that are to replace them.

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* This is a mistake. The chyle is conveyed into the trunk of the absorbent system, called by anatomists the *thoracic duct*. This runs in a serpentine direction along the internal side of the back bone up to the *subclavian vein*, which lies under the collar bone Into this vein the chyle is discharged and mixes with the blood, and before it reaches the heart it is converted into blood itself. C.

Emily. What a great variety of ingredients must enter into the composition of the blood?

Mrs. B. You must observe that there is also a great variety of substances to be secreted from it. We may compare the blood to a general receptacle or storehouse for all kinds of commodities, which are afterwards fashioned, arranged, and disposed of as circumstancs require.

There is another set of asorbent vessels in females which is destined to secrete milk for the nourishment of the young.

Emily. Pray is not milk very analogous in its composition to blood; for, since the nursling derives its nourishment from that source only, it must contain every principle which the animal system requires?

Mrs. B. Very true. Milk is found, by its analysis, to contain the principal materials of animal matter, albumen, oil, and phosphat of lime; so that the suckling has but little trouble to digest and assimilate this nourishment. But we shall examine the composition of milk more fully afterwards.

In many parts of the body numbers of small vessels are collected together in little bundles called *glands*, from a Latin word meaning *acorn*, on account of the resemblance which some of them bear in shape to that fruit. The function of the glands is to *secrete*, or separate certain matters from the blood.

The secretions are not only mechanical, but chemical separations from the blood; for the substances thus formed, though contained in the blood, are not ready combined in that fluid. The secretions are of two kinds, those which form peculiar animal fluids, as bile, tears, saliva, &c.; and those which produce the general materials of the animal system, for the purpose of recruiting and nourishing the several organs of the body; such as albumen, gelatine, and fibrine; the latter may be distinguished by the name of *nutritive secretions.*

Caroline. I am quite astonished to hear that all the secretions should be derived from the blood.

Emily. I thought that the bile was produced by the liver?

Mrs. B. So it is; but the liver is nothing more than a very large gland, which secretes the bile from the blood.

The last of the animal organs which we have mentioned are the *nerves;* these are the vehicles of sensation, every other part of the body being, of itself, totally insensible.

Caroline. They must then be spread through every part of the frame, for we are every where susceptible of feeling.

Emily. Excepting the nails and the hair.

Mrs. B. And those are almost the only parts in which nerves cannot be discovered. The common source of all the nerves is the brain; thence they decend, some of them through different apertures in the skull, but the greatest part through the back bone, and extend themselves by innumerable ramifications throughout the whole body. They spread themselves over the muscles, penetrate the glands, wind round the vascular system, and even pierce into the interior of the bones. It is most probably through them that the communication is carried on between the mind and the other parts of the body; but in what manner they are acted on by the mind, and made to re-act on the body, is still a profound secret. Many hypotheses have been formed on this very obscure subject, but they are all equally improbable, and it would be useless for us to waste our time in conjectures on an enquiry, which, in all probability, is beyond the reach of human capacity.

Caroline. But you have not mentioned those particular nerves that form the senses of hearing, seeing, smelling, and tasting?

Mrs. B. They are considered as being of the same nature as those which are dispersed over every part of the body, and constitute the general sense of feeling. The different sensations which they produce arise from their peculiar situation and connection with the several organs of taste, smell, and hearing.

Emily. But these senses appear totally different from that of feeling?

Mrs. B. They are all of them sensations, but variously modified according to the nature of the different organs in which the nerves are situated. For, as we have formerly observed, it is by contact only that the nerves are affected. Thus odoriferous particles must strike upon the nerves of the nose, in order to excite the sense of smelling; in the same manner that taste is produced by the particular substance coming in contact with the nerves of the tongue. It is thus also that the sensation of sound is produced by the concussion of the air striking against the auditory nerve; and sight is the effect of the light falling upon the optic nerve. These various senses, therefore, are effected only by the actual contact of particles of matter, in the same manner as that of feeling.

The different organs of the animal body, though easily separated and perfectly distinct, are loosely connected together by a kind of spongy substance, in texture somewhat resembling net-work, called the cellular membrane; and the whole is covered by the skin.

The *skin*, as well as the bark of vegetables, is formed of three coats. The external one is called the *cuticle* or *epidermis;* the second, which is called the *mucous membrane*, is of a thin soft texture, and consists of a mucous substance, which in negroes is black, and is the cause of their skin appearing of that colour.

Caroline. Is then the external skin of negroes white like ours?

Mrs. B. Yes; but as the cuticle is transparent, as well as porous, the blackness of the mucous membrane is visible through it. The extremities of the nerves are spread over this skin, so that the sensation of feeling is transmitted through the cuticle. The internal covering of the muscles, which is properly the skin, is the thickest, the toughest, and most resisting of the whole; it is this membrane which is so essential in the arts, by forming leather when combined with tannin.

The skin which covers the animal body, as well as those membranes that form the coats of the vessels, consists almost exclusively of gelatine; and is capable of being converted into glue, size, or jelly.

The cavities betwen the muscles and the skin are usually filled with fat, which lodges in the cells of the membranous net before mentioned, and gives to the external form (especially in the human figure) that roundness, smoothness, and softness, so essential to beauty.

Emily. And the skin itself is, I think, a very ornamental part of the human frame, both from the fineness of its texture, and the variety and delicacy of its tints.

Mrs. B. This variety and harmonious gradation of colours, proceed, not so much from the skin itself, as from the internal organs which transmit their several colours through it, these being only softened and blended by the colour of the skin, which is uniformly of a yellowish white.

Thus modified, the darkness of the veins appears of a pale blue colour, and the floridness of the arteries is changed to a delicate pink. In the most transparent parts, the skin exhibits the bloom of the rose, whilst where it is more opaque its own colour predominates; and at the joints, where the bones are most prominent, their whiteness is often discernible. In a word, every part of the human frame seems to contribute to its external grace; and this not merely by producing a pleasing variety of tints, but by a peculiar kind of beauty which belongs to each individual part. Thus it is to the solidity and arrangement of the bones that the human figure owes the grandeur of its stature, and its firm and dignified deportment. The muscles delineate the form, and stamp it with energy and grace, and the soft substance which is spread over them smooths their ruggedness, and gives to the contours the gentle undulations of the line of beauty. Every organ of sense is a peculiar and separate ornament; and the skin, which polishes the surface, and gives it that charm of colouring so inimitable by art, finally conspires to render the whole the fairest work of the creation.

But now that we have seen in what manner the animal frame is formed, let us observe how it provides for its support, and how the several organs, which form so complete a whole, are nourished and maintained.

This will lead us to a more particular explanation of the internal organs: here we shall not meet with so much apparent beauty, because these parts were not intended by nature to be exhibited to view; but the beauty of design, in the internal organisation of the animal frame, is, if possible, still more remarkable than that of the external parts.

We shall defer this subject till our next interview.

CONVERSATION XXV.

ON ANIMALISATION, NUTRITION, AND RESPIRATION.

Mrs. B. We have now learnt of what materials the animal system is composed, and have formed some idea of the nature of its organisation. In order to complete the subject, it remains for us to examine in what manner it is nourished and supported.

Vegetables, we have observed, obtain their nourishment from various substances, either in their elementary state, or in a very simple state of combination; as carbon, water, and salts, which they pump up from the soil; and carbonic acid and oxygen, which they absorb from the atmosphere.

Animals, on the contrary, feed on substances of the most complicated kind; for they derive their sustenance, some from the animal creation, others from the vegetable kingdom, and some from both.

Caroline. And there is one species of animals, which, not satisfied with enjoying either kind of food in its simple state, has invented the art of combining them together in a thousand ways, and of rendering even the mineral kingdom subservient to its refinements.

Emily. Nor is this all; for our delicacies are collected from the various climates of the earth, so that the four quarters of the globe are often obliged to contribute to the preparation of our simplest dishes.

Caroline. But the very complicated substances which constitute the nourishment of animals, do not, I suppose, enter into their system in their actual state of combination?

Mrs. B. So far from it, that they not only undergo a new arrangement of their parts, but a selection is made of such as are most proper for the nourishment of the body, and those only enter into the system, and are animalised.

Emily. And by what organs is this process performed?

Mrs. B. Chiefly by the stomach, which is the organ of digestion, and the prime regulator of the animal frame.

Digestion is the first step toward nutrition. It consists in reducing into one homogeneous mass the various substances that are taken as nourishment; it is performed by first chewing and mixing the solid aliment with the saliva, which reduces in to a soft mass, in which state it is conveyed into the stomach, where it is more completely dissolved by the *gastric juice.*

This fluid (which is secreted into the stomach by appropriate glands) is so powerful a solvent that scarcely any substances will resist its action.

Emily. The coats of the stomach, however, cannot be attacked by it, otherwise we should be in danger of having them destroyed when the stomach was empty.

Mrs. B. They are probably not subject to its action; as long, at least, as life continues. But it appears, that, when the gastric juice has no foreign substance to act upon, it is capable of occasioning a degree of irritation in the coats of the stomach, which produces the sensation of hunger. The gastric juice, together with the heat and muscular action of the stomach, converts the aliment into an uniform pulpy mass called chyme. This passes into the intestines, where it meets with the bile and some other fluids, by the agency of which, and by the operation of other causes hitherto unknown, the chyme is changed into chyle, a much thinner substance, somewhat resembling milk, which is pumped by immense numbers of small absorbent vessels spread over the internal surface of the intestines. These, after many circumvolutions, gradually meet and unite into large branches, till they at length collect the chyle into one vessel, which pours its contents into the great vein near the heart, by which means the food, thus prepared, enters into the circulation.

Caroline. But I do not yet clearly understand how the blood, thus formed, nourishes the body and supplies all the secretions?

Mrs. B. Before this can be explained to you, you must first allow me to complete the formation of the blood. The chyle may, indeed, be considered as forming the chief ingredient of blood; but this fluid is not perfect until it has passed through the lungs, and undergone (together with the blood that has already circulated) certain necessary changes that are effected by RESPIRATION.

Caroline. I am very glad that you are going to explain the nature of respiration: I have often longed to understand it, for though we talk incessantly of *breathing*, I never knew precisely what purpose it answered.

Mrs. B. It is indeed one of the most interesting processes imaginable; but, in order to understand this function well, it will be necessary to enter into some previous explanations. Tell me, Emily,—what do you understand by respiration?

Emily. Respiration, I conceive, consists simply in alternately *inspiring* air into the lungs, and *expiring* it from them.

Mrs. B. Your answer will do very well as a general definition. But, in order to form a tolerably clear notion of the various phenomena of respiration, there are many circumstances to be taken into consideration.

In the first place, there are two things to be distinguished in respiration, the *mechanical* and the *chemical* part of the process.

The mechanism of breathing depends on the alternate expansions and contractions of the chest, in which the lungs are contained. When the chest dilates, the cavity is enlarged, and the air rushes in at the mouth, to fill up the vacuum formed by this dilatation, when it contracts, the cavity is diminished, and the air forced out again.

Caroline. I thought that it was the lungs that contracted and expanded in breathing?

Mrs. B. They do likewise; but their action is only the consequence of that of the chest. The lungs, together with the heart and largest blood vessels, in a manner fill up the cavity of the chest; they could not, therefore, dilate if the chest did not previously expand: and, on the other hand, when the chests contracts, it compresses the lungs and forces the air out of them.

Caroline. The lungs, then, are like bellows, and the chest is the power that works them.

Mrs. B. Precisely so. Here is a curious little figure (PLATE XV. fig. 5.,) which will assist me in explaining the mechanism of breathing.

Caroline. What a droll figure! a little head fixed upon a glass bell, with a bladder tied over the bottom of it!

Mrs. B. You must observe that there is another bladder within the glass, the neck of whch communicates with the mouth of the figure—this represents the lungs contained within the chest; the other bladder, which you see is tied loose, represents a muscular membrane, called the *diaphragm*, which separates the chest from the lower part of the body. By the chest, therefore, I mean that large cavity in the upper part of the body contained within the ribs, the neck, and the diaphragm; this membrane is muscular, and capable of contraction and dilatation. The contraction may be imitated by drawing the bladder tight over the bottom of the receiver, when the air in the bladder, which represents the lungs, will be forced out through the mouth of the figure—

Emily. See, Caroline, how it blows the flame of the candle in breathing?

Mrs. B. By letting the bladder loose again, we imitate the dilatation of the diaphragm, and the cavity of the chest being enlarged, the lungs expand, and the air rushes in to fill them.

Emily. This figure, I think, gives a very clear idea of the process of breathing.

Mrs. B. It illustrates tolerably well the action of the lungs and diaphragm; but those are not the only powers concerned in the enlargement or diminution of the cavity of the chest; the ribs are also possessed of a muscular motion for the same purpose; they are alternately drawn in, edgeways, to assist the contraction, and stretched out, like the hoops of a barrel, to contribute to the dilatation of the chest.

Emily. I always supposed that the elevation and depression of the ribs were the consequence, not the cause of breathing.

Mrs. B. It is exactly the reverse. The muscular action of the diaphragm, together with that of the ribs, are the *causes* of the contraction and expansion of the chest; and the air rushing into, and being expelled from the lungs, are only *consequences* of those actions.

Caroline. I confess that I thought the act of breathing began by opening the mouth for the air to rush in, and that it was the air alone, which, by alternately rushing in and out, occasioned the dilatations and contractions of the lungs and chest.

Mrs. B. Try the experiment of merely opening your mouth; the air will not rush in, till by an interior muscular action you produce a vacuum—yes, just so, your diaphragm is now dilated, and the ribs expanded. But you will not be able to keep them long in that situation. Your lungs and chest are already resuming their former state, and expelling the air with which they had just been filled. This mechanism goes on more or less rapidly, but, in general, a person at rest and in health will breathe between fifteen and twenty-five times in a minute.

We may now proceed to the chemical effects of respiration; but, for this purpose, it is necessary that you should previously have some notion of the *circulation* of the blood. Tell me, Caroline, what do you understand by the circulation of the blood?

Caroline. I am delighted that you come to that subject, for it is one that has long excited my curiosity. But I cannot conceive how it is connected with respiration. The idea I have of the circulation is, that the blood runs from the heart through the veins all over the body, and back again to the heart?

Mrs. B. I could hardly have expected a better definition from you; it is, however, not quite correct, for you do not distinguish the *arteries* from the *veins*, which, as we have already observed, are two distinct sets of vessels, each having its own peculiar functions. The arteries convey the blood from the heart to the extremities of the body; and the veins bring it back into the heart.

This sketch will give you an idea of the manner in which some of the principal veins and arteries of the human body branch out of the heart, which may be considered as a common centre to both sets of vessels. The heart is a kind of strong elastic bag, or muscular cavity, which possesses a power of dilating and contracting itself, for the purposes of alternately receiving and expelling the blood, in order to carry on the process of circulation.

Emily. Why are the arteries in this drawing painted red, and the veins purple?

Mrs. B. It is to point out the difference of the colour of the blood in these two sets of vessels.

Caroline. But if it is the same blood which flows from the arteries into the veins, how can its colour be changed?

Mrs. B. This change arises from various circumstances. In the first place, during its passage through the arteries, the blood undergoes a considerable alteration, some of its constituent parts being gradually separated from it for the purposes of nourishing the body, and of supplying the various secretions. In consequence of this, the florid arterial colour of the blood changes by degrees to a deep purple, which is its constant colour in the veins. On the other hand, the blood is recruited during its return through the veins by the fresh chyle, or imperfect blood, which has been produced by food; and it receives also lymph from the absorbent vessels, as we have before mentioned. After having undergone these several changes, the blood returns to the heart in a state very different from that in which it left it. It is loaded with a greater proportion of hydrogen and carbon, and is no longer fit for the nourishment of the body, or other purposes of circulation.

Emily. And in this state does it mix in the heart with the pure florid blood which runs into the arteries?

Mrs. B. No. The heart is divided into two cavities or compartitions, called the *right* and *left ventricles*. The left ventricle is the receptacle for the pure arterial blood previous to its circulation; whilst the venous, or impure blood, which returns to the heart after having circulated, is received into the right ventricle, previous to its purification, which I shall presently explain.

Caroline. I own that I always thought the same blood circulated again and again through the body, without undergoing any change.

Mrs. B. Yet you must have supposed that the blood circulated for some purpose?

Caroline. I knew that it was indispensable to life; but had no idea of its real functions.

Mrs. B. But now that you understand that the blood conveys nourishment to every part of the body, and supplies the various secretions, you must be sensible that it cannot constantly answer these objects without being proportionally renovated and purified.

Emily. But does not the chyle answer this purpose?

Mrs. B. Only in part. It renovates the nutritive principles of the blood, but does not relieve it from the superabundance of water and carbon with which it is encumbered.

Emily. How, then, is this effected?

Mrs. B. By RESPIRATION. This is one of the grand mysteries which modern chemistry has disclosed. When the venous blood enters the right ventricle of the heart, it contracts by its muscular power, and throws the blood through a large vessel into the lungs, which are contiguous, and through which it circulates by millions of small ramifications. Here it comes in contact* with the air which we breathe. The action of the air on the blood in the lungs is, indeed, concealed, from our immediate observation; but we are able to form a tolerably accurate judgment of it from the changes which it effects, not only in the blood, but also on the air expired.

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*Not in actual contact. In this case it is obvious there would be nothing to confine the blood and prevent its flowing out. The air cells are separated from the blood vessels by an extremely thin membrane.

The air, after passing through the lungs, is found to contain all the nitrogen inspired, but to have lost part of its oxygen, and to have acquired a portion of watery vapour and of carbonic acid gas. Hence it is inferred, that when the air comes in contact with the venous blood in the lungs, the oxygen attracts from it the superabundant quantity of carbon with which it has impregnated itself during the circulation, and converts it into carbonic acid. This gaseous acid, together with the redundant moisture from the lungs,* being then expired, the blood is restored to its former purity, that is, to the state of arterial blood, and is thus again enabled to perform its various functions.

Caroline. This is truly wonderful! Of all that we have yet learned, I do not recollect any thing that has appeared to me so curious and interesting. I almost believe that I should like to study anatomy now, though I have hitherto had so disgusting an idea of it. Pray, to whom are we indebted for these beautiful discoveries?

Mrs. B. Priestley and Crawford, in this country, and Lavoisier, in France, are the principal inventors of the theory of respiration. Of late years the subject has been farther illustrated and simplified by the accurate experiments of Messrs Allen and Pepys. But the still more important and more admirable discovery of the circulation of the blood was made long before by our immortal countryman, Harvey.

Emily. Indeed I never heard any thing that delighted me so much as this theory of respiration. But I hope, Mrs. B., that you will enter a little more into particulars before you dismiss so interesting a subject. We left the blood in the lungs to undergo the salutary change: but how does it thence spread to all the parts of the body?

Mrs. B. After circulating through the lungs, the blood is collected into four large vessels, by which it is conveyed into the left ventricle of the heart, whence it is propelled to all the different parts of the body by a large artery, which gradually ramifies into millions of small arteries through the whole frame. From the extremities of these little ramifications the blood is transmitted to the veins, which bring it back to the heart and lungs, to go round again and again in the manner we have just described. You see, therefore, that the blood actually undergoes two circulations; the one, through the lungs, by which it is converted into pure arterial blood; the other, or general circulation, by which nourishment is conveyed to every part of the body; and these are both equally indispensible to the support of animal life.

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* The quantity of moisture discharged by the lungs in 24 hours, may be computed at eight or nine ounces.

Emily. But whence proceeds the carbon with which the blood is impregnated when it comes into the lungs?

Mrs. B. Carbon exists in a greater proportion in blood than in organised animal matter. The blood, therefore, after supplying its various secretions, becomes loaded with an excess of carbon, which is carried off by respiration; and the formation of new chyle from the food affords a constant supply of carbonaceous matter.

Caroline. I wonder what quantity of carbon may be expelled from the blood by respiration in the course of 24 hours?

Mrs. B. It appears by the experiments of Messrs. Allen and Pepys that about 40,000 cubic inches of carbonic acid gas are emitted from the lungs of a healthy person, daily; which is equivalent to *eleven ounces* of solid carbon every 24 hours.

Emily. What an immense quantity! And pray how much of carbonic acid gas do we expel from our lungs at each expiration?

Mrs. B. The quantity of air which we take into our lungs at each inspiration, is about 40 cubic inches, which contain a little less than 10 cubic inches of oxygen; and of those 10 inches, one-eighth is converted into carbonic acid gas on passing once through the lungs,* a change which is sufficient to prevent air which has only been breathed once from suffering a taper to burn in it.

Caroline. Pray, how does the air come in contact with the blood in the lungs?

Mrs. B. I cannot answer this question without entering into an explanation of the nature and structure of the lungs. You recollect that the venous blood, on being expelled from the right ventricle, enters the lungs to go through what we may call the lesser circulation; the large trunk or vessel that conveys it branches out, at its entrance into the lungs, into an infinite number of very fine ramifications. The windpipe, which conveys the air from the mouth into the lungs, likewise spreads out into a corresponding number of air vessels, which follow the same course as the blood vessels, forming millions of very minute air-cells. These two sets of vessels are so interwoven as to form a sort of net-work, connected into a kind of spongy mass, in which every particle of blood must necessarily come in contact with a particle of air.

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* The bulk of carbonic acid gas formed by respiration, is exactly the same as that of the oxygen gas which disappears.

Caroline. But since the blood and the air are contained in different vessels, how can they come into contact?

Mrs. B. They act on each other through the membrane which forms the coats of these vessels; for although this membrane prevents the blood and the air from mixing together in the lungs, yet it is no impediment to their chemical action on each other.*

Emily. Are the lungs composed entirely of blood vessels and air vessels?

Mrs. B. I believe they are, with the addition only of nerves and of a small quantity of the cellular substance beforementioned, which connects the whole into an uniform mass.

Emily. Pray, why are the lungs always spoken of in the plural number? Are there more than one?

Mrs. B. Yes; for though they form but one organ, they really consist of two compartments called *lobes*, which are enclosed in separate membranes or bags, each occupying one side of the chest, and being in close contact with each other, but without communicating together. This is a beautiful provision of nature, in consequence of which, if one of the lobes be wounded, the other performs the whole process of respiration till the first is healed.

The blood, thus completed, by the process of respiration, forms the most complex of all animal compounds, since it contains not only the numerous materials necessary to form the various secretions, as saliva, tears, &c. but likewise all those that are required to nourish the several parts of the body, as the muscles, bones, nerves, glands, &c.†

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* It is not absolutely certain that the change which the blood undergoes in the lungs is entirely owing to the loss of carbon; since experiments show that any animal substance, even the hand, when confined in a portion of atmospheric air, lessens the quantity of oxygen, and produces a corresponding quantity of carbonic acid. It is possible, then, that the carbon produced by respiration, may be owing merely to the contact between the air and the lungs. C.

† The process of secretion does not consist merely in the separation of certain materials from the blood by the secreting organ; but in many instances, entirely new products are formed, no traces of which have been detected in the blood. For instance the solid matter of the bones is derived from the blood, yet not a particle of phosphat of lime, (a substance composing the basis of bone,) is found in it. It appears, then, that the *glands* which are the organs of secretion, have the power of *producing* from the ultimate atoms of the blood, the variety of products peculiar to each. Thus the glands situated about the eyes se-

Emily. There seems to be a singular analogy between the blood of animals and the sap of vegetables; for each of these fluids contains the several materials destined for the nutrition of the numerous class of bodies to which they respectively belong.

Mrs. B. Nor is the production of these fluids in the animal and vegetable systems entirely different; for the absorbent vessels, which pump up the chyle from the stomach and intestines, may be compared to the absorbents of the roots of plants, which suck up the nourishment from the soil. And the analogy between the sap and the blood may be still further traced, if we follow the latter in the course of its circulation; for, in the living animal, we find every where organs which are possessed of a power to secrete from the blood and appropriate to themselves the ingredients requisite for their support.

Caroline. But whence do these organs derive their respective powers?

Mrs. B. From a peculiar organisation, the secret of which no one has yet been able to unfold. But it must be ultimately by means of the vital principle that both their mechanical and chemical powers are brought into action.

I cannot dismiss the subject of circulation without mentioning *perspiration*, a secretion which is immediately connected with it, and acts a most important part in the animal economy.

Caroline. Is not this secretion likewise made by appropriate glands?

Mrs. B. No; it is performed by the extremities of the arteries, which penetrate through the skin and terminate under the cuticle, through the pores of which the perspiration issues. When this fluid is not secreted in excess, it is *insensible*, because it is dissolved by the air as it exudes from the pores; but when it is secreted faster than it can be dissolved, it becomes *sensible*, as it assumes its liquid state.

Emily. This secretion bears a striking resemblance to the transpiration of the sap of plants. They both consist of the most fluid parts, and both exude from the surface by the extremities of the vessels through which they circulate.

Mrs. B. And the analogy does not stop there; for, since it has been ascertained that the sap returns into the roots of the plants, the resemblance between the animal and vegetable circulation is become still more obvious. The latter, however, is

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crete the tears, a saline, pellucid fluid; while the liver secretes, from the same source the bile, a greenish, opake, bitter and extremely nauseous substance. It is most probable that we shall ever remain in profound ignorance, of any mode of imitating these operations. C.

far from being complete, since, as we observed before, it consists only in a rising and descending of the sap, whilst in animals the blood actually *circulates* through every part of the system.

We have now, I think, traced the process of nutrition, from the introduction of the food into the stomach to its finally becoming a constituent part of the animal frame. This will, therefore, be a fit period to conclude our present conversation. What further remarks we have to make on the animal economy shall be reserved for our next interview.

CONVERSATION XXVI.

ON ANIMAL HEAT; AND ON VARIOUS ANIMAL PRODUCTS.

Emily. Since our last interview, I have been thinking much of the theory of respiration; and I cannot help being struck with the resemblance which it appears to bear to the process of combustion. For in respiration, as in most cases of combustion, the air suffers a change, and a portion of its oxygen combines with carbon, producing carbonic acid gas.

Mrs. B. I am much pleased that this idea has occurred to you: these two processes appear so very analogous, that it has been supposed that a kind of combustion actually takes place in the lungs; not of the blood, but of the superfluous carbon which the oxygen attracts from it.

Caroline. A combustion in our lungs! that is a curious idea indeed! But, Mrs. B., how can you call the action of the air on the blood in the lungs combustion, when neither light nor heat are produced by it?

Emily. I was going to make the same objection.—Yet I do not conceive how the oxygen can combine with the carbon, and produce carbonic acid, without disengaging heat?

Mrs. B. The fact is, that heat is disengaged.* Whether any light be evolved, I cannot pretend to determine; but that heat is produced in considerable and very sensible quantities is certain, and this is the principal, if not the only source of ANIMAL HEAT.

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* It has been calculated that the heat produced by respiration in 12 hours, in the lungs of a healthy person, is such as would melt about 100 pounds of ice.

Emily. How wonderful! that the very process which purifies and elaborates the blood, should afford an inexhaustable supply of internal heat?

Mrs. B. This is the theory of animal heat in its original simplicity, such nearly as it was first proposed by Black and Lavoisier. It was equally clear and ingenious; and was at first generally adopted. But it was objected, on second consideration, that if the whole of the animal heat was evolved in the lungs, it would necessarily be much less in the extremities of the body than immediately at its source; which is not found to be the case. This objection, however, which was by no means frivolous, is now satisfactorily removed by the following consideration:—Venous blood has been found by experiment to have *less capacity for heat* than arterial blood; whence it follows that the blood, in gradually passing from the arterial to the venus state, during the circulation, parts with a portion of caloric, by means of which heat is diffused through every part of the body.*

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* This is substantially Dr. Crawford's theory of animal heat; and that it is a most beautiful and ingenious one, cannot be denied. Subsequent experiments have however proved its fallacy. Dr. John Davy has shown that the difference of capacity for heat between the two kinds of blood is much less than was supposed by Dr. Crawford—the capacity of arterial being only one per cent, above that of venous blood. Now it is obvious, that this minute difference cannot account for animal temperature; nor is it certain that even this small quantity of heat is given out to the system. Another objection is the result of an experiment of Mr. Brodie. This indeed seems to settle the question that animal heat does not depend on any change which the blood undergoes in the lungs. He found that on keeping up an artificial respiration in the lungs of a decapitated animal, the blood was changed from black to red, and carbonic acid was given out as usual; but that the animal grew cold faster than another dead one, where such artificial respiration was not kept up.

This, it is obvious, would be the case unless heat was caused by respiration, as the air forced into the lungs would tend to cool the animal.

Prof. Cooper of Philadelphia proposes another theory. "I see no material difficulty," says he, "in accounting for the production of animal heat from the doctrine of latent heat. The fluids of the body are incessantly employed to renew the solids: when a fluid is converted into a solid, heat or caloric is precipitated. This takes place every moment very gradually in every part of the system."

We are ignorant of the train of arguments by which the learned Professor supports this theory. But, if on the one hand, the conversion of a fluid into a solid produces heat, so it is equally well proved, that the conversion of a solid into a fluid produces cold. Now the solid parts of the body after being deposited from the fluids, are again converted into fluids by the absorbents. This theory then, accounts

Emily. More and more admirable!

Caroline. The cause of animal heat was always a perfect mystery to me, and I am delighted with its explanation.—But pray, Mrs. B., can you tell me what is the reason of the increse of heat that takes place in a fever?

Emily. Is it not because we then breathe quicker, and therefore more heat is disengaged in the system?

Mrs. B. That may be one reason: but I should think that the principal cause of the heat experienced in fevers, is, that there is no vent for the caloric which is generated in the body. One of the most considerable secretions is the insensible perspiration; this is constantly carrying off caloric in a latent state; but during the hot stage of a fever, the pores are so contracted, that all perspiration ceases, and the accumulation of caloric in the body occasions those burning sensations which are so painful.

Emily. This is, no doubt, the reason why the perspiration which often succeeds the hot stage of a fever affords so much relief. If I had known this theory of animal heat when I had a fever last summer, I think I should have found some amusement in watching the chemical processes that were going on within me.

Caroline. But exercise likewise produces animal heat, and that must be quite in a different manner.

Mrs. B. Not so much so as you think; for the more exercise you take, the more the body is stimulated, and requires recruiting. For this purpose the circulation of the blood is quickened, the breath proportionably accelerated, and consequently a greater quantity of caloric evolved.

Caroline. True; after running very fast, I gasp for breath,

for the production of heat only when the deposition is greater than the absorption, as during the growth of the system.

From some experiments, made by Mr. Brodie and Dr. Philip, they have been induced to believe that animal temperature depends on the influence of the nerves.

In regard to this theory it may be observed, that in some instances where the nervous influence seems to be suspended, the heat of the part remains much the same as in health.

This subject has excited the attention of the learned and curious in all ages, and a great variety of theories have been offered to account for it. We have seen none, however, to which insuperable objections may not be brought. We must therefore, at present, be contented with attributing the production of animal warmth to the energies of the *vital principle;* leaving it to future generations to determine and define its immediate cause. C.

my respiration is quick and hard, and it is just then that I begin to feel hot.

Emily. It would seem, then, that violent exercise should produce fever.

Mrs. B. Not if the person is in a good state of health; for the additional caloric is then carried off by the perspiration which succeeds.

Emily. What admirable resources nature has provided for us! By the production of animal heat she has enabled us to keep up the temperature of our bodies above that of inanimate objects; and whenever this source becomes too abundant, the excess is carried off by perspiration.

Mrs. B. It is by the same law of nature that we are enabled, in all climates, and in all seasons, to preserve our bodies of an equal temperature, or at least very nearly so.

Caroline. You cannot mean to say that our bodies are of the same temperature in summer, and in winter, in England, and in the West-Indies.

Mrs. B. Yes, I do; at least if you speak of the temperature of the blood, and the internal parts of the body; for those which are immediately in contact with the atmosphere, such as the hands and face, will occasionally get warmer, or colder, than the internal or more sheltered parts. If you put the bulb of a thermometer in your mouth, which is the best way of ascertaining the real temperature of your body, you will scarcely perceive any difference in its indication, whatever may be the difference of temperature of the atmosphere.

Caroline. And when I feel overcome by heat, I am really not hotter than when I am shivering with cold?

Mrs. B. When a person in health feels very hot, whether from internal heat, from violent exercise, or from the temperature of the atmosphere, his body is certainly a little warmer than when he feels very cold; but this difference is much smaller than our sensations would make us believe; and the natural standard is soon restored by rest and by perspiration. It is chiefly the external parts that are warmer, and I am sure that you will be surprised to hear that the internal temperature of the body scarcely ever descends below ninety-five or ninety-six degrees, and seldom attains one hundred and four or one hundred and five degrees, even in the most violent fevers.

Emily. The greater quantity of caloric, therefore, that we receive from the atmosphere in summer, cannot raise the temperature of our bodies beyond certain limits, as it does that of inanimate bodies, because an excess of caloric is carried off by perspiration.

Caroline. But the temperature of the atmosphere, and consequently that of inanimate bodies, is surely never so high as that of animal heat?

Mrs. B. I beg your pardon. In the East and West Indies, and sometimes in the southern parts of Europe, the atmosphere is frequently above ninety-eight degrees, which is the common temperature of animal heat. Indeed, even in this country, it occasionally happens that the sun's rays, setting full on an object, elevate its temperature above that point.

In illustration of the power which our bodies have to resist the effects of external heat, Sir Charles Blagden, with some other gentlemen, made several very curious experiments. He remained for some time in an oven heated to a temperature not much inferior to that of boiling water, without suffering any other inconvenience than a profuse perspiration, which he supported by drinking plentifully.

Emily. He could scarcely consider the perspiration as an inconvenience, since it saved him from being baked by giving vent to the excess of caloric.

Caroline. I always thought, I confess, that it was from the heat of the perspiration that we suffered in summer.

Mrs. B. You now find that you are quite mistaken. Whenever evaporation takes place, cold, you know, is produced in consequence of a quantity of caloric being carried off in a latent state; this is the case with perspiration, and it is in this way that it affords relief. It is on that account also that we are apt to *catch cold*, when in a state of profuse perspiration. It is for the same reason that tea is often refreshing in summer, though it appears to heat you at the moment you drink it.

Emily. And in winter, on the contrary, tea is pleasant on account of its heat.

Mrs. B. Yes; for we have then rather to guard against a deficiency than an excess of caloric, and you do not find that tea will excite perspiration in winter, unless after dancing, or any other violent exercise.

Caroline. What is the reason that it is dangerous to eat ice after dancing, or to drink any thing cold when one is very hot?

Mrs. B. Because the loss of heat arising from the perspiration, conjointly with the chill occasioned by the cold draught, produce more cold than can be borne with safety, unless you continue to use the same exercise after drinking that you did before; for the heat occasioned by the exercise will counteract the effects of the cold drink, and the danger will be removed. You may, however, contrary to the common notion, consider it as a rule, that cold liquids may, at all times, be drunk with perfect safety, however hot you may feel,[*] provided you are not at the moment in a state of great perspiration, and on condition that you keep yourself in gentle exercise afterwards.

Emily. But since we are furnished with such resources against the extremes of heat or cold, I should have thought that all climates would have been equally wholesome.

Mrs. B. That is true, in a certain degree, with regard to those who have been accustomed to them from birth; for we find that the natives of those climates, which we consider as most deleterious, are as healthy as ourselves; and if such climates are unwholesome to those who are habituated to a more moderate temperature, it is because the animal economy does not easily accustom itself to considerable changes.

Caroline. But pray, Mrs. B., if the circulation preserves the body of an uniform temperature, how does it happen that animals are sometimes frozen?

Mrs. B. Because, if more heat be carried off by the atmosphere than the circulation can supply, the cold will finally prevail, the heart will cease to beat, and the animal will be frozen. And, likewise, if the body remained long exposed to a degree of heat, greater than the perspiration could carry of, it would at last lose the power of resisting its destructive influence.

Caroline. Fish, I suppose, have no animal heat, but only partake of the temperature of the water in which they live?[†]

Emily. And their coldness, no doubt, proceeds from their not breathing?

Mrs. B. All kinds of fish breathe more or less, though in a much smaller degree than land animals. Nor are they entirely destitute of animal heat, though, for the same reason, they are much colder than other creatures. They have comparatively but a very small quantity of blood, therefore but very little oxygen is required, and a proportionally small quantity of animal heat is generated.

Caroline. But how can fish breathe under water?

Mrs. B. They breathe by means of the air which is dissolved in the water, and if you put them into water deprived of air by boiling, they are soon suffocated.

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[*] The common notion on this subject is certainly the most safe. A person heated, and almost exhausted by exercise on a hot day, ought never to drink any cold liquid, except in very small quantities at a time. Not a summer passes but we hear of deaths by drinking cold water after violent exercise. C.

[†] Animals belonging to the order *Cetæ* of Naturalists, though they inhabit the sea, breathe atmospheric air, and have hot, red blood. This order includes the *whales*, *dolphins*, *narwals*, &c. C.

If a fish is confined in a vessel of water closed from the air, it soon dies; and any fish put in afterwards would be killed immediately, as all the air had been previously consumed.

Caroline. Are there any species of animals that breathe more than we do?

Mrs. B. Yes; birds, of all animals, breathe the greatest quantity of air in proportion to their size; and it is to this that they are supposed to owe the peculiar firmness and strength of their muscles, by which they are enabled to support the violent exertion of flying.

This difference between birds and fish, which may be considered as the two extremes of the scale of muscular strength, is well worth observing. Birds residing constantly in the atmosphere, surrounded by oxygen, and respiring it in greater proportions than any other species of animals, are endowed with a superior degree of muscular strength, whilst the muscles of fish, on the contrary, are flaccid and oily; these animals are comparatively feeble in their motions, and their temperature is scarcely above that of the water in which they live. This is, in all probability, owing to their imperfect respiration; the quantity of hydrogen and carbon, that is in consequence accumulated in their bodies, ~~forms the~~ oil which is so strongly characteristic of that species of animals, and which relaxes and softens the small quantity of fibrine which their muscles contain.

Caroline. But, Mrs. B., there are some species of birds that frequent both elements, as, for instance, ducks and other water fowl. Of what nature is the flesh of these?

Mrs. B. Such birds, in general, make but little use of their wings; if they fly, it is but feebly, and only to a short distance. Their flesh, too, partakes of the oily nature, and even in taste sometimes resembles that of fish. This is the case not only with the various kinds of water fowls, but with all other amphibious animals, as the otter, the crocodile, the lizard, &c.

Caroline. And what is the reason that reptiles are so deficient in muscular strength?

Mrs. B. It is because they usually live under ground, and seldom come into the atmosphere. They have imperfect, and sometimes no discernible organs of respiration; they partake, therefore, of the soft oily nature of fish; indeed, many of them are amphibious, as frogs, toads, and snakes, and very few of them find any difficulty in remaining a length of time under water.* Whilst, on the contrary, the insect tribe, that are so strong in proportion to their size; and alert in their motions, partake of the nature of birds, air being their peculiar element, and their organs of respiration being comparatively larger than in other classes of animals.

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* Amphibious animals have the power of suspending respiration for

I have now given you a short account of the principal animal functions. However interesting the subject may appear to you, a fuller investigation of it would, I fear, lead us too far from our object.

Emily. Yet I shall not quit it without much regret; for of all the applications of chemistry, these appear to me the most curious and most interesting.

Caroline. But, Mrs. B., I must remind you that you promised to give us some account of the nature of *milk*.

Mrs. B. True. There are several other animal productions that deserve likewise to be mentioned. We shall begin with milk, which is certainly the most important and the most interesting of all the animal secretions.

Milk, like all other animal substances, ultimately yields by analysis oxygen, hydrogen, carbon, and nitrogen. These are combined in it under the forms of albumen, gelatine, oil, and water. But milk contains, besides a considerable portion of phosphat of lime, the purposes of which I have already pointed out.

Caroline. Yes; it is this salt which serves to nourish the tender bones of the suckling.

Mrs. B. To reduce milk to its elements, would be a very complicated, as well as useless operation; but this fluid, without any chemical assistance, may be decomposed into three parts, *cream*, *curds* and *whey*. These constituents of milk have but a very slight affinity for each other, and you find accordingly that cream separates from milk by mere standing. It consists chiefly of oil, which being lighter than the other parts of the milk, gradually rises to the surface. It is of this, you know, that butter is made, which is nothing more than oxygenated cream.

Caroline. Butter, then, is somewhat analogous to the waxy substance formed by the oxygenation of vegetable oils.

Mrs. B. Very much so.

Emily. But is the cream oxygenated by churning?

Mrs. B. Its oxygenation commences previous to churning, merely by standing exposed to the atmosphere, from which it absorbs oxygen. The process is afterwards completed by

a considerable time. It is in consequence of this, that they are enabled to live under water. C.

churning; the violent motion which this operation occasions brings every particle of cream in contact with the atmosphere, and thus facilitates its oxygenation.

Caroline. But the effect of churning, I have often observed in the dairy, is to separate the cream into two substances, butter and butter-milk.

Mrs. B. That is to say, in proportion as the oily particles of the cream become oxygenated, they separate from the other constituent parts of the cream in the form of butter. So by churning you produce, on the one hand, butter, or oxygenated oil; and, on the other, butter-milk, or cream deprived of oil. But if you make butter by churning new milk instead of cream, the butter-milk will then be exactly similar in its properties to creamed or skimmed milk.

Caroline. Yet butter-milk is very different from common skimmed milk.

Mrs. B. Because you know it is customary, in order to save time and labour, to make butter from cream alone. In this case, therefore, the butter-milk is deprived of the creamed milk, which contains both the curd and whey. Besides, in consequence of the milk remaining exposed to the atmosphere during the separation of the cream, the latter becomes more or less acid, as well as the butter-milk which it yields in churning.

Emily. Why should not the butter be equally acidified by oxygenation?

Mrs. B. Animal oil is not so easily acidified as the other ingredients of milk. Butter, therefore, though usually made of sour cream, is not sour itself, because the oily part of the cream had not been acidified. Butter, however, is susceptible of becoming acid by an excess of oxygen; it is then said to be rancid, and produces the sebacic acid, the same as that which is obtained from fat.

Emily. If that be the case, might not rancid butter be sweetened by mixing with it some substance that would take the acid from it?

Mrs. B. This idea has been suggested by Sir H. Davy, who supposes, that if rancid butter were well washed in an alkaline solution, the alkali would separate the acid from the butter.

Caroline. You said just now that creamed milk consisted of curd and whey. Pray how are these separated?

Mrs. B. They may be separated by standing for a certain length of time exposed to the atmosphere; but this decomposition may be almost instantaneously effected by the chemical agency of a variety of substances. Alkalies, rennet,* and indeed almost all animals substances, decompose milk by combining with the curds.

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* Rennet is the name given to a watery infusion of the coats of the

Acids and spirituous liquors, on the other hand, produce a decomposition by combining with the whey. In order, therefore, to obtain the whey pure, rennet, or alkaline substances, must be used to attract the curds from it.

But if it be wished to obtain the curds pure, the whey must be separated by acids, wine, or other spiritous liquors.

Emily. This is a very useful piece of information; for I find white-wine whey, which I sometimes take when I have a cold, extremely heating; now, if the whey were separated by means of an alkali instead of wine, it would not produce that effect.

Mrs. B. Perhaps not. But I would strenuously advise you not to place too much reliance on your slight chemical knowledge in medical matters. I do not know why whey is not separated from curd by rennet, or by an alkali, for the purpose which you mention; but I strongly suspect that there must be some good reason why the preparation by means of wine is generally preferred. I can, however, safely point out to you a method of obtaining whey without either alkali, rennet, or wine; it is by substituting lemon juice, a very small quantity of which will separate it from the curds.

Whey, as an article of diet, is very wholesome, being remarkable light of digestion. But its effect, taken medicinally, is chiefly, I believe, to excite perspiration, by being drunk warm on going to bed.

From whey a substance may be obtained in crystals by evaporation, called *sugar of milk*. This substance is sweet to the taste, and in its composition is so analogous to common sugar, that it is susceptible of undergoing the vinous fermentation.

Caroline. Why then is not wine, or alcohol, made from whey?

Mrs. B. The quantity of sugar contained in milk is so trifling, that it can hardly answer that purpose. I have heard of only one instance of its being used for the production of a spirituous liquor, and this is by the Tartan Arabs; their abundance of horses, as well as their scarcity of fruits, has introduced the fermentation of mares' milk, by which they produce a liquor called *koumiss*. Whey is likewise susceptible of being acidified by combining with oxygen from the atmosphere. It

stomach of a sucking calf. Its remarkable efficacy in promoting coagulation is supposed to depend on the gastric juice with which it is impregnated.

then produces the *lactic acid*, which you may recollect is classed with the animal acids, as the acid of milk.

Let us now see what are the properties of curds.

Emily. I know that they are made into cheese; but I have heard that for that purpose they are separated from the whey by rennet, and yet this you have just told us is not the method of obtaining pure curds?

Mrs. B. Nor are pure curds so well adapted for the formation of cheese. For the nature and flavour of the cheese depend, in a great measure, upon the cream or oily matter which is left in the curds; so that if every particle of cream be removed from the curds, the cheese is scarcely eatable. Rich cheeses, such as cream and Stilton cheeses, derive their excellence from the quantity, as well as the quality, of the cream that enters into their composition.

Caroline. I had no idea that milk was such an interesting compound. In many respects there appears to me to be a very striking analogy between milk and the contents of an egg, both in respect to their nature and their use. They are, each of them, composed of the various substances necessary for the nourishment of the young animal, and equally destined for that purpose.

Mrs. B. There is however, a very essential difference. The young animal is formed, as well as nourished, by the contents of the egg-shell; whilst milk serves as nutriment to the suckling, only after it is born.

There are several peculiar animal substances which do not enter into the general enumeration of animal compounds, and which, however, deserve to be mentioned.

Spermaceti is of this class; it is a kind of oily substance obtained from the head of the whale, which, however, must undergo a certain preparation before it is in a fit state to be made into candles. It is not much more combustible than tallow, but it is pleasanter to burn, as it is less fusible and less greasy.

Ambergris is another peculiar substance derived from a species of whale. It is, however, seldom obtained from the animal itself, but is generally found floating on the surface of the sea.

Wax, you know, is a concrete oil, the peculiar product of the bee, part of the constituents of which may probably be derived from flowers, but so prepared by the organs of the bee, and so mixed with its own substance, as to be decidedly an animal product. Bees' wax is naturally of a yellow colour, but it is bleached by long exposure to the atmosphere, or may be instantaneously whitened by the oxy-muriatic acid. The combustion of wax is far more perfect than that of tallow, and consequently produces a greater quantity of light and heat.

Lac is a substance very similar to wax in the manner of its formation; it is the product of an insect, which collects its ingredients from flowers, apparently for the purpose of protecting its eggs from injury. It is formed into cells, fabricated with as much skill as those of the honey-comb, but differently arranged. The principal use of lac is in the manufacture of sealing-wax, and in making varnishes and lacquers.

Musk, *civet*, and *castor*, are other particular productions, from different species of quadrupeds. The two first are very powerful perfumes; the latter has a nauseous smell and taste, and is only used medicinally.

Caroline. Is it from this substance that castor oil is obtained?

Mrs. B. No. Far from it, for castor oil is a vegetable oil, expressed from the seeds of a particular plant; and has not the least resemblance to the medicinal substance obtained from the castor.

Silk is a peculiar secretion of the silk-worm, with which it builds its nest or cocoon. This insect was originally brought to Europe from China. Silk, in its chemical nature, is very similar to the hair and wool of animals; whilst in the insect it is a fluid, which is coagulated, apparently by uniting with oxygen, as soon as it comes in contact with the air. The moth of the silk-worm ejects a liquor which appears to contain a peculiar acid, called *bombic*, the properties of which are but very little known.

Emily. Before we conclude the subject of the animal economy, shall we not learn by what steps dead animals return to their elementary state?

Mrs. B. Animal matter, although the most complicated of all natural substances, returns to its elementary state by one single spontaneous process, the *putrid fermentation.* By this, the albumen, fibrine, &c. are slowly reduced to the state of oxygen, hydrogen, nitrogen, and carbon; and thus the circle of changes through which these principles have passed is finally completed. They first quitted their elementary form, or their combination with unorganised matter, to enter into the vegetable system. Hence they were transmitted to the animal kingdom; and from this they return again to their primitive simplicity, soon to re-enter the sphere of organised existence.

When all the circumstances necessary to produce fermentation do not take place, animal, like vegetable matter, is liable to a partial or imperfect decomposition, which converts it into a combustible substance very like spermaceti. I dare say that

Caroline, who is so fond of analogies, will consider this as a kind of animal bitumen.

Caroline. And why should I not, since the processes which produce these substances are so similar?

Mrs. B. There is, however, one considerable difference; the state of bitumen seems permanent, whilst that of animal-substances, thus imperfectly decomposed, is only transient; and unless precautions be taken to preserve them in that state, a total dissolution infallibly ensues. This circumstance, of the occasional conversion of animal matter into a kind of spermaceti, is of late discovery. A manufacture has in consequence been established near Bristol, in which, by exposing the carcases of horses and other animals for a length of time under water, the muscular parts are converted into this spermaceti-like substance. The bones afterwards undergo a different process to produce hartshorn, or more properly, ammonia, and phosphorus; and the skin is prepared for leather.

Thus art contrives to enlarge the sphere of useful purposes, for which the elements were intended by nature; and the productions of the several kingdoms are frequently arrested in their course, and variously modified, by human skill, which compels them to contribute, under new forms, to the necessities or luxuries of man.

But all that we enjoy, whether produced by the spontaneous operations of nature, or the ingenious efforts of art, proceed alike from the goodness of Providence.—To God alone man owes the admirable faculties which enable him to improve and modify the productions of nature, no less than those productions themselves. In contemplating the works of the creation, or studying the inventions of art; let us, therefore, never forget the Divine Source from which they proceed; and thus every acquisition of knowledge will prove a lesson of piety and virtue.

DESCRIPTION OF THE APHLOGISTIC, OR FLAMELESS LAMP.

BY DR. J. L. COMSTOCK, OF HARTFORD.

In the construction of this Lamp, the object is to keep a coil of wire in a state of ignition, without either flame or smoke.

The principle on which it is constructed, I believe, was first discovered by Sir H. Davy. He found that on heating the end of a piece of *platina* wire red hot, and instantly holding it near the surface of some *ether*, placed in a wine glass, the wine was kept at a red heat as long as the experiment was continued.

Whether Sir Humphrey pursued the subject any further, I am not informed. It is most probable however that he did not, as it is stated in a London paper of the last year, that Prof. Ure of Glasgow had determined the circumstances which modify the performance of the lamp, and that one constructed by him was in full operation in that city (London) and had excited much public curiosity. This notice contained some directions, concerning the size of the wire, to be used, and the manner of coiling it. I have however seen no description of this lamp which would enable one readily to construct it. The following may therefore interest such readers, as have seen an account of so curious a discovery.

The principle on which the aphlogistic lamp is constructed involves two conditions, which are absolutely requisite, viz. that we make use of a combustible substance which evaporates at a low degree of heat, and a metal which is a bad conductor of caloric. For the combustible, alcohol seems best suited to this purpose. *Sulphuric ether*, aside from its high price, and disagreeable smell, I have sometimes found to fail; the ignition ceasing without any obvious cause.

In regard to the metal, gold and silver, both fail in consequence of the rapidity with which they conduct caloric. Silver, too, would soon be destroyed by the intense heat. Iron, although so bad a conductor, as to remain ignited for a time, soon fails, being converted into red oxide. Platina seems to be the only metal adapted to our purpose, being a slow conductor of caloric, and not easily oxidated at the highest temperatures.

This is to be drawn into wire of 56-100 or 60-100 of an inch in diameter, being about the size of card, or brass wire, No. 26. Experience has shown that this size succeeds better than any other. If larger, the heat is carried off too fast, and the ignition ceases. If much finer, it does not retain sufficient heat at the lower part of the coil to keep up the evaporation of the alcohol from the wick.

The coiling of the wire, and the adjustment of the wick, are the most difficult parts of the construction.

The coil A. fig. 1. *(frontispiece)* is made by winding the wire round a piece of wood, cut of the proper size, and shape. The size is determined by the bore of the glass tube, allowing for the diameter of the wire. The shape is plane cylindrical in that part which enters the tube; and slightly conical where it projects above the tube, as seen in the figure. (I believe this is the best shape, though I have succeeded as well when the coil was of the same shape throughout.)

In winding the coil, it is best that the turns of the wire should come in contact. Afterwards it is to be gently extended, so as to leave the turns as nearly as possible to each other, without touching.

The diameter of the coil is about one-sixth of an inch where it enters the tube. Its length half an inch, or a little less, containing from twenty to thirty turns of the wire. The projection above the tube is about one half of the length.

B. Fig. 1. is a glass tube, containing a cotton wick, which by capillary attraction carries the alcohol up to the platina coil. The length of this is arbitrary, being from one to three or four inches. The bore is about the sixth of an inch, so as barely to admit the coil. The wick, consisting of eight or ten threads, is first drawn through the tube, and then introduced about half way into the coil, so as to come even with the top of the tube. This requires very nice adjustment. If the wick is too high, the wire is rapidly cooled by the alcohol, and ignition ceases in a few moments. If too low, the evaporation by the heat of the wire is insufficient. If, however, the other parts are well constructed, a few trials will ensure success.

Fig. 2. shows the lamp complete. The body of it is a low vial, or inkstand, capable of holding about two ounces of alcohol. It is stopped accurately with a cork, which is covered, for ornament, with tin foil. The aperture for admitting the tube and wick, is make with a hot iron.

D. is a small tube through which the alcohol is poured. A *dropping* tube is convenient for this purpose, but a small funnel is easily made by cutting off an inch of the neck of a broken retort, into which is pushed a cork, and through this a small quill. Another orifice still, for letting off the air, as the alcohol goes in, may be made through the cork. The orifices, of course, are to be stopped, to prevent evaporation, after the lamp is charged.

When the lamp is completed and charged, the alcohol is inflamed by holding the coil in the blaze of a candle. After letting it burn for a few minutes, the flame is blown out, when, if every thing is properly adjusted, the wire will continue red hot until the alcohol is exhausted.

The explanation why the ignition of the wire is permanent, seems to be sufficiently simple. Alcohol, when in the state of vapour, combines with oxygen with great facility. The temperature of the wire is first raised by the flame of the candle to about 600 degrees, Fahrenheit. This degree of heat is such as to effect the combustion of the alcohol with the oxygen of the atmosphere. When this is once effected, the caloric extricated by the combustion of the alcohol, is sufficient to keep the coil at a red heat, which again is the temperature at which the alcohol is combustible, so that one portion of alcohol by the absorption of oxygen, and the consequent extrication of heat, lays the foundation for the combustion of another portion: and as the alcohol rises in a constant stream, so the effect is constant. The stream of vapour is much increased by the heat of the lower part of the coil, where it embraces the wick, and the temperature of the alcohol is increased before it reaches the part of the coil where combustion is effected. Sometimes the last, or upper turn of the wire only is kept red hot.

This lamp, though one of the most curious inventions of the age, is not merely a curiosity. The facility and certainty with which, by means of a match, a light may be obtained from it, constitutes its utility. The proper matches for this purpose are prepared by dipping the common brimstone matches into a paste made by mixing two parts of white sugar with one part of chlorate (oxymuriat) of potash. The red French matches are of this kind, and answer the purpose completely.

In cases where a light might be wanted, but a constant one would be offensive, this lamp might be a great convenience; a light being immediately obtained by merely touching a match to the platina coil, and then to the wick of the candle. Physicians or others who are liable to be called up in the night would also find it convenient.

The aphlogistic lamp, with the proper matches may be obtained at Mr. Charles Hosmer's Variety Store in this city.

QUESTIONS FOR EXERCISE.

CONVERSATION I.

WHAT is the object of Chemistry?
What is an *elementary substance*?
What is *decomposition*?
What is the difference between decomposition and *division*?
What is a *compound* body?
What is the number of elementary substances?
What is the difference between *attraction* of *cohesion*, and *attraction* of *composition*?
How can a compound body be decomposed?
What are the names and number of the simple bodies?

CONVERSATION II.

Is there an inseparable connection between *light* and *heat*?—How can they be separated?
To what is the phosphorescence of dead animal matter owing?
How do you distinguish heat and light from each other?
What is *free caloric*?
What is *combined* or *latent* caloric?
What is the difference between heat and caloric?
What is the most remarkable effect of free caloric on bodies?
Does heat expand all bodies in the same degree?
What is the temperature of boiling water?
Why cannot water be heated above a certain degree in the open air?
Why was the freezing point of Fahrenheit marked 32°?
Why do air thermometers indicate smaller changes of temperature than others?
Can you name any substance, or any known condition of a substance in which caloric is absent?
What is cold?
Why does a metallic mirror feel cold when placed before the fire?
What kind of a surface radiates most heat?
Why do metallic coffee pots retain the heat of the coffee longer than earthen ones?
What becomes of the caloric radiated by a hot body?

What is the difference between the *radiation* and *reflection* of caloric?

CONVERSATION III.

Why do some substances feel hotter, or colder, than others, at the same temperature?
Do fluids conduct caloric downwards?
How are fluids heated when placed over a fire?
Why does water first freeze at the surface?
Why does not the surface of the sea freeze?
Why does a fire heat glass, when the sun does not?
Why, in the summer, is it particularly hot in cloudy, or foggy weather?
Why is the wind cooling to our bodies?
Does water boil from the top, or bottom of the vessel?
What are the principle *solvent* fluids?
What is the difference between *solution* and *mixture*?
Is a fluid increased in bulk by the solution of a solid?
When is a solvent *saturated*?
What is *evaporation*?
When does the air contain most moisture? in winter or summer?
How do you account for the formation of *dew*?
Why is a glass of cold water covered with moisture in hot weather?
Why does the evaporation of ether freeze water?
How does *ignition* differ from *combustion*?

CONVERSATION IV.

What is understood by *capacity* for caloric?
Have all bodies of the same weight the same capacity for caloric?
How is the capacity of bodies for heat ascertained?
What is latent caloric?
How does latent caloric differ from specific caloric?
Why does not the thermometer rise in a warm room, when its bulb is in a piece of ice?
How much latent heat does water contain?
Is the real zero known to exist?
How can ice be made in the summer?
Why does the slaking of lime produce heat?

CONVERSATION V.

What kind of body is electricity ?
How many metals are required to produce the galvanic action ?
Can galvanism be produced without water ?
How many kinds of electricity are there ?
What were the ideas of Dr. Franklin on this subject ?
What is said to produce the heat of the electric fluid ?
What is the difference between electricity and galvanism ?
What difference does it make in the action of the galvanic battery, whether you increase the number of plates, or enlarge their dimensions ?

CONVERSATION VI.

Of what is the atmosphere composed ?
What is a gas ?
To what do the gases owe their elasticity ?
What proportions of oxygen and nitrogen constitute common air ?
When a substance burns, what does it absorb ?
Why is it necessary to heat a combustible substance to make it burn ?
Why does a candle confined in a small portion of air soon go out ?
How does *oxygenation* differ from *combustion* ?
Why is there no smoke when the fire burns best ?
Do the constituents of the atmosphere exist in a state of chemical combination ?

CONVERSATION VII.

What does the word *hydrogen* signify ?
How does hydrogen produce water ?
Of what is water composed ?
What are the means of decomposing water ?
What the results of galvanic action upon water ?
How much lighter is hydrogen than common air ?
Will oxygen and hydrogen combine in any other proportion than that which forms water ?
In the burning of a candle, why is there a little space of wick, left between the tallow and flame ?
What is the gas called which is used in lighting streets ?
How is this gas procured ?

Describe the miner's lamp.
What is the use of this lamp?

CONVERSATION VIII.

Where is sulphur obtained?
How does *brimstone* differ from the *flowers* of *sulphur*?
What is sublimation?
When sulphur is burned, what is the product?
From whence is phosphorus obtained?
What is the result of its combustion?
How are the *phosphorus* and *phosphoric* acid formed?
Does phosphoric combine with hydrogen?
What are the singular properties of phosphuret of lime?

CONVERSATION IX.

What is carbon?
Under what form does crystallised charcoal appear?
Why does charcoal burn without a blaze?
What becomes of carbon during its combustion?
Is it possible to burn a diamond?
What is the product of its combustion?
Does carbon unite with more than one proportion of oxygen?
Is it safe to breathe carbonic acid?
Why does a small quantity of water increase the flame of a fire?
What is the composition of *black lead*?
How may the adulteration of volatile oil be detected?
What are the products of a burning candle or lamp?
How does carbon restore oxydated substances to their combustible state?

CONVERSATION X.

How many metals are there?
Name them.
Where are the metals found?
How are they refined?
Are all the metals combustible?
What are oxides?
What use is made of metallic oxides?
How is the most intense heat produced?
Do the metals oxydate on being exposed to the air?
When a metal dissolves in an acid, what causes the heat?

What state must a metal be in before it can be dissolved by an acid?

What is crystallization?

Do any of the metals combine with so much oxygen as to become acids?

At what degree of cold does mercury become solid?

From whence do the metallic oxides derive their poisonous qualities?

What peculiarities have the new metals, discovered by Sir H. Davy?

CONVERSATION XIII.

What is the attraction of composition?

What is the kind of attraction which brings acids and alkalies to unite?

What are the seven laws of chemical attraction?

What are the *salifiable bases?*

What are the *salifiable principles?*

How do salts ending in *ate* differ from those ending in *ite?*

How do acids ending in *ic* differ from those ending in *ous?*

How are chemical compositions, and decompositions effected?

What is meant by *quiescent*, and *divellant* forces?

When acids and alkalies unite in several proportions, what relation do these proportions bear to each other?

When a salt is decomposed by galvanism, at which pole does the acid appear?

CONVERSATION XIV.

What are the alkalies?

What is their composition?

What are the general properties of the alkalies?

On what does the *causticity* of the alkalies depend?

To what colour do the alkalies change the vegetable blues?

From whence is potash obtained?

What is the chemical name of *potash?*

What is its composition?

Why is heat disengaged when water is poured on caustic potash?

What is the result when potash is melted with silex?

What is the chemical name of *salt petre?*

What is its composition?

From whence does *soda* derive its name?

How is it obtained?

How does *soda* differ from *potash*?
Why is the volatile alkali called *ammonia*?
From what is it extracted?
By what means can *ammonia* be separated from the *muriatic acid*?
Under what form does it appear when pure?
What is the composition of *ammonia*?
How can ammoniacal gas be retained for experiments without a mercurial bath?
How do you account for the production of cold, when ice is melted with ammoniacal gas?
What is the substance used in smelling bottles, called *hartshorn*?
What is formed when ammonia unites with oil?
From what class of substances can ammonia be extracted?

CONVERSATION XV.

What is the number of earths, and what their names?
Why are they incombustible?
What costly substances do the earths compose?
With what are the gems coloured?
Which are the *alkaline* earths?
What substances contain silica in the greatest abundance?
What is the composition of *Derbyshire spar*?
What are the important uses of silex?
From whence does *alumine* derive its name?
From what substance is this earth obtained?
In what kind of soil does it occur most abundantly?
Is it useful in the arts, or otherwise, and for what purposes?
Name the alkaline earths.
Of what use is *barytes*?
Has it any remarkable properties?
In what respect does caustic lime differ from lime-stone?
What is the process of making *quick-lime*?
What effect does the air produce on quick-lime?
What effect has water on it?
What is the cause of the heat, when lime is sprinkled with water?
Does it dissolve in water, and in what proportion?
What is the process of making lime-water?
For what has lime a remarkable affinity?
Why does lime-water turn white on breathing into it?
Of what use is lime in the arts?
Of what use is it in agriculture?

What are the principal uses of *magnesia?*
Does it attract water?
In what state is it used in medicine?
What does it form when combined with *sulphuric acid?*
Is *strontion* of any use?
What are its peculiarities?

CONVERSATION XVI.

What is an *acid?*
What are the general properties of the acids?
What is meant by the *radical* of an acid?
What substance unites to the radical to form an acid?
How does the language of chemistry distinguish the stronger from the weaker acid?
What term is used to denote the first degree of oxygenation?
When a radical unites with another proportion of oxygen after that denoted by *ic*, what term is used?
Are all the acids capable of equal degrees of oxygenation?
What is the number of acids?
How many kinds of acids are there?
Name the acids which are known to have simple bases.
Which are called *mineral* acids?
Of what are the radicals of the vegetable acids composed?
Why do these acids differ, when composed of the same radicals?
What are the names of the vegetable acids?
Name the acids with triple radicals.
What is their composition, and from whence are they obtained?
By what means can the acids of simple radicals be decomposed?
Why does sulphuric acid change the colour of wood to black?
Why do not the vegetable acids produce the same effect?
What is the reason the vegetable acids are not decomposed by combustibles?
Do the mineral acids have the same effect upon the skin that they do on wood? If they do not what is the reason?

CONVERSATION XVII.

What is the chemical name of oil of vitriol?
What is the colour and smell of sulph. acid?
What is its specific gravity?
What is the consequence of mixing it with water?
What is the process for obtaining sulp. acid?
What the best antidote, when a quantity is swallowed?
How can the sulphur*ic* acid be changed to the sulphur*ous?*

What use is made of sulphurous acid?
What is the easiest process for making this acid?
Define what the term *salt* means.
What is the chemical name and composition of *Glauber's salt*?
How can sulphate of soda be formed?
What qualities in the salts are denoted by the terms *efflorescent* and *deliquescent*?
From whence comes sulph. of alumine?
What are its principal uses?
How is sulphate of iron manufactured in the large way?
What substance strikes a black colour with sulph. of iron?
Why does the cutting of an apple turn the blade of the knife black?
Where is *phosphate* of lime chiefly found?

CONVERSATION XVIII.

What acids are formed by the combination of *nitrogen* and *oxygen*?
What acid contains the greatest proportion of oxygen?
Explain the reason why nitric acid inflames charcoal, oil, turpentine, &c.
How is nitric acid obtained, and from what substance?
How can *nitric*, be converted in *nitrous*, acid; and what is the cause of the change?
Why does nitric acid act with peculiar energy on combustibles?
How can *nitrous air* be procured from nitric acid, and what is the principle?
How is nitrous air converted into *nitrous acid gas*?
On what principle can nitrous air be applied to test the purity of the atmosphere? What is the process?
How is the *exhilarating* gas procured?
Describe the process of making *nitrate of ammonia.*
What caution is necessary before it is breathed?
When do chemical decompositions and combinations take place during the formation of this gas from nitrate of ammonia?
Why is *nitrate of potash* used in making *gun powder*, rather than any other salt?
What causes the *detonation* when gun powder is fired?
What gas is formed when charcoal is burned in oxygen gas?
By what method can charcoal be procured from carbonic acid?
What portion of the atmosphere is formed of this gas?
By what means is this gas procured for experiment?
From whence came the immense quantity of carbonic acid contained in limestone rocks?

In what manner does this gas destroy life?
What effect does it have on vegetation?
What are the waters called which contain this gas?
What are the salts called which are partly composed of this gas?
How extensive is this class of salts, and under what forms do they chiefly occur in nature?

CONVERSATION XIX.

What is the basis of *boracic* acid?
What is the composition of borax?
What are its uses?
From whence is *fluoric acid* obtained?
What are its peculiar properties?
Describe the method of *etching on glass.*
With what is *muriatic acid* chiefly found combined?
What is the *natural* state in which this exists?
How can this gas be confined without a mercurial bath?
What is the basis of muriatic acid?
Is this acid capable of combining with different proportions of oxygen?
Why is not the least degree of oxygenation called the *muriatous acid*?
How is *oxy-muriatic* acid obtained?
Explain the reason why metals inflame in this gas.
Why does a mixture of nitric, and muriatic acids dissolve gold, when neither of them will do it alone?
Why does oxy-muriatic acid turn the colour of vegetables *white*?
Of what use is this acid in the arts?
Why is oxy-muriatic acid lately called *chlorine*?
What are the reasons for supposing that chlorine is a simple substance?
What are the reasons for supposing that it is not a simple substance?
From whence, and by what process is *muriate of soda* obtained?
What two gases, when mixed form *muriate* of *ammonia*? Describe the experiment.
What are the peculiar properties of *oxy-muriate of potash*?
Why does it explode on being rubbed with charcoal, sulphur, &c.
What gases are generated at the moment of explosion with charcoal? Explain the changes which take place, and the cause of the detonation.

How can phosphorus be set on fire at the bottom of a vessel of water? and how do you account for it?

What are the peculiarities of *iodine*?

How can you show the *violet* coloured gas?

From whence is iodine obtained?

Why is it considered a simple body?

CONVERSATION XX.

What are *organised* bodies, and how do they differ from inorganic matter?

Define what life is.

What constitutes the simplest class of organised bodies?

Of what are vegetables chiefly composed?

What are the materials of vegetables?

Is any part of a plant composed of a single ingredient?

Why do vegetables decompose, when the principle of life is extinguished?

Vegetables are susceptible of two kinds of analysis, what is the object of each?

What is *mucilage*, and what are its uses?

Can gum be used as food?

What proportion of vegetables contain *sugar*?

In what manner is sugar obtained from the *sugar cane*?

How does *honey* differ from sugar?

What is *fecula*?

What is *gluten*?

How many kinds of vegetable *oils* are there?

From what part of plants are fixed oils obtained?

What are the principal *drying* oils?

On what does this quality depend?

Why do painters add oxyd of lead to their oils?

To what is the *rancidity* of oil owing?

Is there any known method of *making* oil by combining its principles?

How do *volatile* differ from *fixed* oils?

How are volatile oils obtained?

When they are adulterated with fixed oils how can the fraud be detected?

From whence does *camphor* come, and from what is it extracted?

What is the method of obtaining it?

Is camphor contained in other plants?

What are *resins*?

How are *varnishes* prepared?

What are *gum-resins*?
What are *balsams*?
Give some account of *caoutchouc* or gum-elastic.
What is extractive matter?
What is the condition required to form a good *dye*?
Explain the nature and uses of *mordants*.
What substances are commonly used as mordants?
What is *tannin*?
How is *artificial* tannin made?
What is *woody* fibre?
Of what is it chiefly composed?
What are the names of the *vegetable acids*?
What is the composition of the bases of these acids?
What is the *gallic* acid?
What are *galls*, and how are they formed?
How does the *oxalic* acid remove ink spots?

CONVERSATION XXI.

What are the *elements* into which vegetables are reduced by *natural* decomposition?
What is the process called which *disunites* and *decomposes* the elements of vegetables?
How many kinds of *fermentation* are there?
What circumstances are necessary to induce this process?
Give some account of the *saccharine* fermentation.
What is the process of making malt?
What changes do the ingredients of the barley undergo to form malt?
What is the second fermentation called?
Why does barley resist the *vinous* fermentation until it has gone through the *saccharine*?
What changes take place among the ingredients present, during the *vinous* fermentation?
What is the principal difference between *alcohol* and *sugar*?
When wine is *distilled*, what is the product?
How does sugar differ from starch?
What difference is there between gin and brandy?
What is the origin of *cream of tartar*?
On what does the intoxicating quality of liquors depend?
What is the composition of *alcohol*?
Describe the spirit lamp.
How is *ether* obtained?
How does it differ from alcohol?
What is the effect of the *acetous* fermentation?

What is the reason that wine, or cider, when corked tight does not turn to vinegar?
What kind of fermentation is excited by the yeast to make bread?
What is the final operation of nature to reduce vegetables to their elements?
How are *petrifactions* formed?
What are *bitumens*, and how are they formed?
Why does *naptha* preserve potassium?
What is *asphaltum*?
What is *coal*, and what are its ingredients?
How does *coke* differ from coal?
What is *amber*, and where is it found?

CONVERSATION XXII.

From whence do all animals ultimately derive their sustenance?
From whence do plants derive their food?
Will plants live on pure water?
Why do animal substances make the best *manure*?
What part of the seed are the *cotyledons*?
What is the *radicle*? What is the *plumule*?
What purpose do each of these answer during *germination*?
What office do the leaves of plants perform during their growth?
What different functions do the two sides of the leaves perform?
What is essential to the developement of the colours of plants?
Why is *air* necessary to the growth of plants?
In what way does animal and vegetable life mutually support each other?
Through what vessels does the *sap* of plants ascend?
What is the distinction between *alburnum*, and *heart-wood*?
How is *pitch*, *tar*, and *turpentine* obtained?
Why do vegetables grow, only during the warm season?

CONVERSATION XXIII.

What are the fundamental principles of *animal* compounds?
What are the immediate materials of animal compounds?
What is *gelatine*? What use is made of it in the arts, or in medicine?
From what substance is gelatine extracted?
By what means may it be extracted from bones?
Of what is *soup* composed?
How does *glue* differ from gelatine?

What is *albumen*?
Why is silver tarnished by the white of an egg?
What is *fibrine*?
How may it be procured?
In what respect does the composition of *animal* oil, differ from the oil of vegetables?
What are the bases of the *animal* acids?
What are the names of those which are found ready formed in animal substances?
What animal acids are produced by decomposition?
By what means is the *prussic acid* procured?
Does this acid exist ready formed in blood?
By what chemical combinations is it produced?
How is it, that this colourless acid is the colouring matter of prussian blue?
What is *carmine*? How is it prepared?
What is *ivory black*?

CONVERSATION XXIV.

What is *animalisation*?
What is *nutrition*?
What are the principal organs by which the operations of the animal system is performed?
What are the ingredients of the *bones*?
From whence do infants obtain *phosphat* of lime?
How are the teeth formed?
Under what circumstance is the phosphate of lime assimilated in adult animals?
What causes the disease in infants, called the *rickets*?
How are the bones connected together?
What are the uses of the *cartilages*?
What are the *muscles*?
Where are they situated, and what are their uses?
What part in the circulation of the blood does the *arteries* perform?
What part do the *veins* perform?
What is the nature of the *lymph*?
What is *chyle*?
What is its use?
What is the composition of *milk*?
What functions do the *glands* perform?
Does the blood contain all the substances found in the products of secretion?
What offices do the *nerves* perform?

What is the source of the nervous system?
What parts of the animal system are without nerves?
How is it that the nerves convey different sensations, when they all have a common source?
Of how many coats is the skin comprised?
What are they called?
Where is the colour of the skin situated?
What difference in colour is there between the cuticle of a white man, and a black one?

CONVERSATION XXV.

What is *digestion*?
Where is it performed?
What is the solvent of the food in the stomach?
Are the coats of the stomach liable to be destroyed by the *gastric juice*?
What produces the sensation of hunger?
What is the aliment called after it has been acted on by the gastric juice?
What changes does the *chyme* undergo before it is absorbed?
By what system of vessels is the *chyle* taken up?
How does it obtain admittance into circulation?
In what does *respiration* consist?
What constitutes the *mechanical* part of this process?
By what means is the chest expanded so as to admit air into the lungs?
How many times does a person breathe in a minute?
Describe the circulation of the blood.
How does *arterial* blood differ from *venous*?
How do you account for the difference of colour between them?
What are the two cavities of the heart called?
Which cavity receives the arterial, and which the venous blood?
What change does the blood undergo in its passage through the lungs?
What effect does respiration have on the air we breathe?
The blood undergoes two circulations; what is the difference between them?
What is the quantity of carbon expelled from the lungs of a person in 24 hours?
What quantity of air do we take into our lungs at each inspiration?
Is it absolutely certain that the carbon emitted by respiration comes from the blood?
Are all the products of secretion contained in the blood?

If not, how is it most probable that these new substances are formed?

By what system of vessels is the *perspiration* secreted?

CONVERSATION XXVI.

What analogy is there between the effects of respiration, and those of combustion?

What is the principal source of *animal heat*?

What are the objections to Black's theory of animal heat?

How are these objections obviated?

What objections can be brought against Dr. Crawford's theory?

What does Mr. Brodie's experiment prove?

What are the objections to Dr. Cooper's theory?

What are the objections against Dr. Philip's theory?

Why is the heat increased during a fever?

Why does not violent exercise greatly increase the temperature of the body?

On what principle is it that the temperature of the body remains the same in winter as in summer?

Is the temperature of a living animal raised by being exposed to a heat, greater than that of its own body?

How is it proved that fish cannot live without air?

What effect does the respiration of a large or small quantity of air have on the muscular powers of animals?

Why are amphibious animals enabled to remain a long time under water?

What is composition of *milk*?

What are the ingredients in milk?

What does *cream* absorb from the atmosphere to turn it into *butter*?

Why does the *butter-milk* become sour when the butter separated from it is sweet?

What causes butter to become *rancid*?

What does *rennet* contain which causes the coagulation of milk?

What is *spermaceti*?

What is *ambergris*?

By what process does dead animal matter return to its elementary state?

A VOCABULARY
OF
CHEMICAL TERMS.

A.

Acetates. Compounds formed by the combination of a base with acetic acid.

Acids. Compounds formed by the combination of oxygen with certain elementary bodies forming in general a class of substances, which are sour to the taste, and which unite with alkalies, and metallic oxides to form salts.

Acidules. Substances formed by the natural combination of some acids with a quantity of potash. The *oxalic* and tartaric acids are examples.

Aëriform fluids. Elastic fluids. Atmospheric air, and the gases are of this kind. Their aëiform state is owing to the caloric with which their bases are combined.

Affinity, chemical. A term used to express that peculiar propensity which substances of different kinds have to unite with each other, as acids and alkalies, &c.

——— *of aggregation.* That force is so called by which substances of the same kind tend to unite, without changing their qualities.

——— *of composition.* That force by which substances of different kinds combine, and form a third, which differs from either of the two first, before the combination. Thus muriatic acid and soda form common salt.

Albumen. Coagulable lymph. It is contained in animal substances, as the serum of the blood. The white of eggs is albumen.

Alcohol. Rectified spirit of wine. It is always the same, from whatever kind of spirit it is distilled.

Alkalies. Peculiar substances which have a caustic burning taste, and a strong tendency to combination, particularly with acids, and with water.

Alloys. A combination of any two metals, except mercury. Brass is an alloy of copper and zinc.

Amalgam. A mixture of mercury with any other metal.

Analysis. Separation of the constituent parts of compounds, for the purpose of detecting their composition. This is done by *reagents.*

Annealing. Rendering substances tough, which before were brittle. The metals are annealed by heating them red hot, and then cooling them gradually.

Arseniates. Salts formed by the combination of a base with the arsenic acid.

Azote. This name is given by the French chemists to *nitrogen,* which see.

B.

Balsams. Resinous, semi-fluid substances, which are obtained from certain trees by making incisions.

Barometer. An instrument which indicates the variations of the pressure of the atmosphere, as thermometers do of heat and cold.

Base. A term used by chemists to denote the substance to which an acid is united to form a salt. Thus *soda* is the *base* of common salt.

Benzoates. Salts formed by the union of the *benzoic* acid with a base.

Blow-Pipe. An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes.

Borates. Salts formed by the combination of any base with the acid of borax.

C.

Calcareous. A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid.

Calcination. The application of heat to saline, metallic, or other substances; so regulated as to deprive them of moisture, &c. and yet preserve them in a pulverulent form.

Caloric. The chemical term for the matter of heat.

——— *free.* Is caloric in a separate state, or, if attached to other substances, not *chemically* united with them.

——— *latent.* Is the term made use of to express that portion of caloric which is chemically united to any substance, so as to become a *part* of the said substance.

Calorimeter. An instrument for ascertaining the quantity of caloric disengaged from any substance that may be the object of experiment.

Calx. An old term made use of to describe a metallic oxide.

Camphorates. Salts formed by the combination of any base with the camphoric acid.

Capillary. A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

Carbon. The basis of charcoal.

Carbonates. Salts formed by the combination of any base with carbonic acid.

Carburets. Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron.

Causticity. That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity.

Chalybeate. A term descriptive of those mineral waters which are impregnated with iron.

Charcoal. Wood burnt in close vessels: it is an oxide of carbon, and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas.

Chlorine. A name lately given to the substance usually called oxymuriatic acid. Its compounds are called by the name of their bases with the ending of *ane*. As phosphorane, sulphurane, &c.

Chromates. Salts formed by the combination of any base with the chromic acid.

Citrates. Salts formed by the combination of any base with citric acid.

Coal. A term applied to the residuum of any dry distillation of animal or vegetable matters.

Cohesion. A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces.

Columbates. Salts formed by the combination of any base with the columbic acid.

Combination. A term expressive of a true *chemical* union of two or more substances; in opposition to mere mechanical mixture.

Combustibles. Certain substances which are capable of combining more or less rapidly with oxygen. They are divided by chemists into simple and compound combustibles.

Combustion The act of absorption of oxygen by combustible bodies from atmospheric or vital air. The word decombustion is sometimes used by the French writers to signify the opposite operation.

Crucibles. Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone.

Crystallization. An operation of nature, in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures.

————*water of.* That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances.

Cupel. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

D.

Decomposition. The separation of the constituent principles of compound bodies by chemical means.

Deflagration. The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. It may be attributed to the extrication of oxygen from the nitre, and its being transferred to the inflammable body; as any of the nitrates or oxygenized muriates will produce the same effect.

Deliquescence of solid saline bodies, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid.

Deoxidize (formerly deoxidate.) To deprive a body of oxygen.

Deoxidizement. A term made use of to express that operation by which one substance deprives another substance of its oxygen. It is called unburning a body by the French chemists.

Detonation. An explosion with noise. It is most commonly applied to the explosion of nitre when thrown upon heated charcoal.

Digestion. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

Digestor, Papin's. An apparatus for reducing animal or vegetable substances to a pulp or jelly expeditiously.

Distillation A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

Ductility. A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture.

Dulcification. The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

E.

Edulcoration. Expressive of the purification of a substance by washing with water.

Effervescence. An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

Efflorescence. A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization.

Elasticity. A force in bodies, by which they endeavour to restore themselves to the posture from whence they were displaced by an external force.

Elastic fluids. A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

Elective Attractions. A term used by Bergman and others to designate what we now express by the words chemical *affinity.* When chemists first observed the power which one compound substance has to decompose another, it was imagined that the minute particles of some bodies had a *preference* for some other particular bodies; hence this property of matter acquired the term *elective* attraction.

Elements. The simple, constituent parts of bodies which are incapable of decomposition; they are frequently called principles.

Empyreuma. A peculiar and indescribably disagreeable smell, arising from the burning of animal and vegetable matter in close vessels.

Ethers. Volatile liquids formed by the distillation of some of the acids with alcohol.

Evaporation. The converson of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

Eudiometer. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry*.

F.

Fermentation. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature.

Fibrine. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre.

Flowers. In chemical language, are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal ammoniac, of sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

Fluates. Salts formed by the combination of any base with fluoric acid.

Fluidity. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric.

Flux. A substance which is mixed with metallic ore, or other bodies to promote their fusion; as an alkali is mixed with silex, in order to form glass.

Fulmination. Thundering or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated.

Fusion. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

Gallates. Salts formed by the combination of any base with gallic acid.

Galvanism. A new science which offers a variety of phenomena, resulting from different conductors of electricity placed in different circumstances of contact; particularly the nerves of the animal body.

Gas. All solid substances, when converted into permanently elastic fluids by caloric, are called gases.

Gaseous. Having the nature and properties of gas.

Gasometer. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines.

Gelatine. A chemical term for animal gelly. It exists particularly in the tendons and the skin of animals.

Gluten. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

Grain. The *smallest* weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *avoirdupois* pound contains 7000 grains.

Granulation. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

Gravity, specific. This differs from absolute gravity in as much as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals.

Gums. Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen with a little phosphoric acid.

H.

Heat, matter of. See *Caloric.*

Hermetically. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence a tube which was closed for chemical purposes, was said to be Hermetically or chemically sealed. It is usually done by melting the end of the tube by means of a blowpipe.

Hydrogen. A simple substance; one of the constituent parts of water.

——— *gas.* Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. Hence it is used to inflate balloons. It was formerly called inflammable air.

Hydro-Carbonates. Combinations of carbon with hydrogen are described by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation.

Hydrogenized sulphurets. Certain bases combined with sulphuretted hydrogen.

Hydro-Oxides. Metallic oxides combined with water.

Hydrometers. Instruments for ascertaining the specific gravity of spiritous liquors or other fluids.

Hygrometers Instruments for ascertainiug the degree of moisture in atmospheric air.

Hyperoxygenized. A term applied to substances which are combined with the largest possible quantity of oxygen. We have muriatic acid, oxygenized muriatic acid, and hyperoxygenized muriatic acid. The latter can be exhibited only in combination.

I.

Inflammation. A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid is an instance of this peculiar chemical effect.

Infusion. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

Intermediates. A term made use of when speaking of chemical affinity. Oil, for example, has no affinity for water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

K.

Kali. A genus of marine plants which is burnt to procure mineral alkali by afterwards lixiviating the ashes.

L.

Laboratory. A room fitted up with apparatus for the performance of chemical operations.

Lactates. Salts formed by the combination of any base with lactic acid.

Lakes. Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumine, or with oxide of tin, zinc, &c.

Lamp, Argand's. A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

Lens. A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat.

Levigation. The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

Litharge. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead.

Lixiviation. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

Lixivium. A fluid impregnated with an alkali or with a salt.

Lute. A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation.

M.

Maceration. The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

Malates. Salts formed by the combination of any base with malic acid.

Malleability. That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric.

Massicot. A name given to the *yellow* oxide of lead, as minium is applied to the *red* oxide.

Matrass. Another name for a bolt-head.

Menstruum. The fluid in which a *solid* body is dissolved. Thus water is a menstruum for salts, gums, &c. and spirit of wine for resins.

Metallic Oxides. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible substances; and receive the property of being soluble in acids.

Mineral. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

Mineralizers. Those substances which are combined with metals in their ores; such are sulphur, arsenic, oxygen, carbonic acid, &c.

Mineralogy. The science of fossils and minerals.

Mineral Waters. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

Molybdates. Salts formed by the combination of any base with the molybdic acid.

Mordants. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

Mucilage. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

Mucites. Salts formed by the combination of any base with the mucous acid.

Muffle. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

Muriates. Salts formed by the combination of any base with muriatic acid.

N.

Natron. One of the names for mineral alkali, or soda.

Neutralize. When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

Neutral Salt. A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

Nitrates. Salts formed by the combination of any base with nitric acid.

Nitrogen. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air.

O.

Ochres. Various combinations of the earths with oxide, or carbonate, of iron.

Ores. Metallic earths, which frequently contain several extraneous matters; such as sulphur, arsenic, &c.

Oxalates. Salts formed by the combination of any base with oxalic acid.

Oxide. Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

Oxidize. To combine oxygen with a body without producing acidity.

Oxidizement. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity.

Oxygen. A simple substance composing the *greatest* part of water, and part of atmospheric air.

——— *gas.* Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air.

Oxygenize. To acidify a substance by oxygen. Synonymous with Oxygenate; but the former is the better term.

Oxygenizement. The production of acidity by oxygen.

P.

Pellicle. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

Phlogiston. An old chemical name for an imaginary substance, supposed to be a combination of fire with some other matter, and a constituent part of all inflammable bodies, and of many other substances.

Phosphates. Salts formed by the combination of any base with phosphoric acid.

Phosphites. Salts formed by the combination of any base with phosphorous acid.

Phosphurets. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c.

Plumbago. Carburet of iron, or the *black lead* of commerce.

Pneumatic. Any thing relating to the airs and gases.

——— *trough.* A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another.

Precipitate. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum or for the matter which was before held in solution.

Precipitation. That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

Prussiates. Salts formed by the combination of any base with prussic acid.

Putrefaction. The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them by future attractions, in the production of new compositions.

Pyrites. An abundant mineral found on the English coasts, and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumine and silex. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called Marcasites and Fire-stone.

——— *martial.* That species of pyrites which contains iron for its basis. See a full accouut of these minerals in Henckel's Pyritologia.

Pyrometer. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires. See Philosophical transactions, vol. lxii. and lxiv. and Chemical Catech.

Pyrophori. Compound substances which heat of themselves, and take fire on the admission of atmospheric air. See an account of a variety of experiments with these compositions in Wiegleb's Chemistry, quarto, page 622, &c.

Q.

Quartz. A name given to a variety of siliceous earths, mixed with a small portion of lime or alumine. Mr. Kirwan confines the term to the *purer* kind of silex. Rock crystal and the amethyst are species of quartz.

R.

Radicals. A chemical term for the *Elements* of bodies; which see.

——— *compound.* When the base of an acid is composed of two or more substances, it is said that the acid is formed of a *compound* radical. The sulphuric acid is formed with a *simple* radical; but the vegetable acids, which have radicals composed of hydrogen, and carbon, are said to be acids with compound radicals.

Reagents. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition.

Realgar. Red sulphurretted oxide of arsenic.

Receivers. Globular glass vessels adapted to retorts for the

Sulphures, or *Sulphurets*. Combinations of alkalies, or metals with sulphur.

Sulphuretted. A substance is said to be sulphuretted when it is combined with sulphur. Thus we may say Sulphuretted hydrogen, &c.

Super-Salts. Salts with an excess of acid, as the supertartrate of potass.

Synthesis. When a body is examined by *dividing* it into its component parts, it is called *analysis*; but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

T.

Tartrates. Salts formed by the combination of any base with the acid of tartar.

Temperature. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body.

Test. That part of a cupel which is impregnated with litharge in the operation of refining lead. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition.

Test-Papers. Papers impregnated with certain chemical reagents; such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids and alkalies.

Thermometer. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. Other thermometers are used in different parts of Europe.

Tinctures. Solutions of substances in spirituous menstrua.

Trituration. A chemical operation whereby substances are united by friction. Amalgams are made by this method.

Tubulated. Retorts which have a hole at the top for inserting the materials to be operated upon without taking them out of the sand heat, are called *tubulated* retorts.

Tungstates. Salts formed by the combination of any base with tungstic acid.

V.

Vacuum. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

Vapour. This term is used by chemists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.

Vital Air. Oxygen gas. The empyreal or fire-air of Scheele, and the dephlogisticated air of Priestly.

Vitrification. When certain mixtures of solid substances, such as silex and an alkali, are exposed to an intense heat, so as to be fused, and become glass, they are then said to be vitrified, or to have undergone vitrification.

Vitriols. A class of substances, either earthy or metallic, which are combined with the vitriolic acid. Thus there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called Sulphates, because the acid which forms them is called sulphuric acid.

Vitriolated Tartar. The old name for sulphate of potass.

Volatile Alkali. Another name for ammonia.

Volatile Salts. The commercial name for carbonate of ammonia.

Volatility. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

Volume. A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

U.

Union chemical. When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chemical* union.

W.

Water. The most common of all fluids, composed of 85 parts of oxygen and 15 of hydrogen.

——— *mineral.* Waters which are impregnated with mineral and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

Way, dry. A term used by chemical writers when treating of analysis or decomposition. By decomposing in the dry way, is meant, by the agency of fire.

Way humid. A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water, and chemical re-agents, or tests.

Welding Heat. That degree of heat in which two pieces of iron or of platina may be united by hammering.

Wolfram. An ore of tungsten containing also manganese and iron.

Worm-Tub. A chemical vessel with a pewter worm fixed in the inside, and in the intermediate space filled with water. Its use is to cool liquors during distillation.

Woulfe's apparatus. A contrivance for distilling the mineral acids and other gaseous substances with little loss; being a train of receivers with safety-pipes, and connected together by tubes.

Z.

Zaffre. An oxide of cobalt, mixed with a portion of siliceous matter. It is imported in this state from Saxony.

Zero. The point from which the scale of a thermometer is graduated. Thus Celsius's and Reaumur's thermometers have their zero at the *freezing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt.

LIST OF EXPERIMENTS.

In making up the following list of experiments I have been careful in general to select such as can be made with safety to the young student; where this is not the case the caution is mentioned. Most of them require but very simple apparatus. Where any experiment illustrates the text, a reference is made to the page. Some of them are original, others are borrowed. I have not however deemed it necessary to cite authors.

1. To show that heat is not absorbed, but reflected by polished metallic surfaces, hold a common new tin-pan before the fire. The pan will remain cold. See p. 29.

2. To show the power of a black surface to absorb caloric, smoke, or paint black a spot of the size of a dollar on the bottom of the tin-pan; and hold it towards the fire. On touching this spot, it will be found hot, while the parts around it remain cold. See p. 31.

3. To make the upper part of a vessel of water boil, while there is a cake of ice at the bottom. Into a glass tube put water enough to occupy two inches. Freeze this, so as not to burst the tube, with a freezing mixture, or by exposure to cold in winter. Then fill the tube nearly full of water, and wind a flannel cloth several times around the part containing the ice, so that the heat of the hand will not melt it. Then hold the tube in an oblique direction over a lamp, so as to heat the water an inch or two above the ice. The water will soon begin to boil, and by raising the tube a little at a time, it will boil almost to the surface of the ice, without melting it. See p. 39.

4. To show that some of the metals conduct caloric better than others, procure wires of the same size and length, of gold, silver, copper, iron, zinc, tin, &c. The wires may be 12 or 14 inches long. Coat one end of each with bees-wax, and put the other ends into a vessel of hot water. The wax will melt first on the metal which is the best conductor, and the comparative conducting powers are calculated by the difference of time between the melting of the wax on each. See p. 35.

5. The conducting powers of different substances in regard to caloric, may be much more sensibly elucidated, by touching in cold weather, a metal with one hand, and a piece of cork, wood, or cloth with the other. Here the sensation of cold, to the hand which touches the metal, is owing to the power which all

metals have of conducting off heat, more rapidly than any other class of substances. See p. 37.

6. To show that evaporation carries off caloric, moisten the bulb of a thermometer tube with *ether*, by means of a hair pencil. The mercury immediately begins to fall, and if the process be continued, may be brought down to the freezing point, even in warm weather. Whenever a fluid substance is converted into vapour, it absorbs a quantity of caloric. In the present case, the ether takes from the bulb of the thermometer, the caloric necessary to give it the elastic form. Therefore, every new application of the ether carries off successive portions of heat, and the mercury continues to sink, until the bulb becomes so cold, as to absorb caloric from the surrounding air, faster than it is carried off by the evaporation. This is the reason why the mercury cannot be depressed below a certain point by evaporation. The ether, although it assumes the elastic form, does not receive the caloric necessary for this purpose from the thermometer, but from the surrounding air. See p. 53.

7. To demonstrate that fluids boil at comparatively small degrees of heat, when the pressure of the atmosphere is taken off, about half fill with water a small retort, or Florence flask (common oil flask,) and let it boil over a lamp. When the upper part is filled with steam, take it from the lamp, and instantly cork it air tight. If now it is put into cold water, it begins to boil violently. If taken out of the water, it stops boiling, and this may be done many times. This curious method of making water boil by the application of cold, is easily accounted for. When the flask is put into cold water, the steam with which it was filled, is condensed and returns again to water This leaves a *vacuum*, in which water is converted into steam, or boils, at a much lower temperature than in the open air. See p. 55.

8. If the above experiment is made by means of a small retort, a very curious circumstance may be observed: When the water is cold, and consequently nearly a perfect vacuum is formed, if the retort is shaken, there is produced a sharp rattling noise, as though it contained shot, instead of water, so that one would suppose by the noise that the retort would be broken into a thousand parts at every motion. This is owing to the weight with which the water falls upon the glass, when there is no air to impede its motion.

9. Into a thin glass vessel, pour an ounce or two of water, and then pour in two drams of sulphuric acid; the glass will instantly become too hot to be held in the hand. This experi-

ment elucidates the doctrine of latent heat. On mixing these two fluids, a chemical combination takes place between their particles, in consequence of which caloric is extricated, at the same time their bulk is diminished. This also illustrates Dr. Black's law, that when substances pass from a rarer to a denser state, caloric is given out. If one measure of sulphuric acid, and one of water, be mixed together, the mixture will not again fill the measure twice. See p. 69.

10. To procure *nitrogen*, take a bell glass, or large tumbler, and invert it over a short taper, set in a shallow dish of water. The taper burns until it absorbs all the oxygen contained in the air under the bell glass. What remains is nitrogen. If now a lighted taper be put under the bell glass, it will be instantly extinguished, showing the absolute necessity of oxygen for the support of combustion. See p. 85, 89.

11. The formation of water by the burning of hydrogen may be shown thus: Take a Florence flask and pour into it half a pint of water, then put in about an ounce of granulated zinc, or the same quantity of iron filings, and then pour in half an ounce by measure of sulphuric acid. Have ready a cork, pierced with a burning iron, and the stem of a tobacco pipe passed through the aperture. After putting in the acid, put the cork in its place, and fix the flask upright by setting it in a bowl, surrounded by a cloth, to make it stand up and prevent its breaking. As the hydrogen is formed, it issues through the stem of the tobacco pipe, at the end of which it is to be fixed. If now a glass tube two or three feet long and an inch or two wide be passed on to the stem so as to include the flame within its bore, the tube, in a few moments will be covered on the inside with moisture. See p. 106.

If the orifice of the tube is quite small at the end where the gas is fired, the above experiment serves to produce the *musical tones*. See p. 108.

12. An exhibition of *gas light* may be made as follows: Into the bowl of a common tobacco pipe put a piece of *mineral*, or what is called *sea-coal*, and cover the coal closely with clay. When the clay is dry, place the bowl in the fire and heat it slowly. In a few minutes the gas, called *carburetted* hydrogen will issue from the end of the pipe stem; set fire to it with a candle, and it will burn with a beautiful bright flame. This is gas with which the streets, factories &c. are lighted in many of the European cities.

In the absence of mineral coal, a walnut, small piece of pine knot, or butternut meat &c. may take the place of the coal. See p. 114.

13. The following gives an example of the manner in which sulphuric acid is formed.

Mix with a small quantity of the flowers of sulphur, about one fifth part of finely pulverized nitre. Make a stand by hollowing with a hammer a large button, and attaching wire to the eye, for feet, so that the button will be two inches high;—or by any other means, place the sulphur and nitre about this heighth in a shallow dish, containing an inch or two of water. Set fire to the mixture with a hot iron, and immediately invert over it a bell glass, or large tumbler. The sulphur, as it burns, absorbs oxygen from the air contained under the bell glass, in a proportion which would constitute sulphur*ous* acid. At the same time the heat which this process occasions, compels the nitre to give out another proportion of oxygen, which is absorbed by the sulphurous acid, and this additional quantity of oxygen, constitutes sulphur*ic* acid. See p. 121.

14. Take three parts of nitre, two of potash and one of sulphur, and mix them intimately, by rubbing in a mortar. This compound is called *fulminating powder*. On placing a little of it on a shovel over a hot fire, it explodes with great violence, and with a peculiarly stunning report.

15. The combustion of *phosphuretted hydrogen* in oxygen gas, affords one of the most striking, and beautiful, among chemical experiments. It is done as follows: Take some phosphuret of lime, wrap it in a paper and push it under a vessel, as a wide mouthed vial, filled with water, and inverted on the shelf of the water bath. As soon as the water penetrates through the paper so as to wet the phosphuret of lime, bubbles of phosphuretted hydrogen, begin to rise up through the water. While this is going on, fill a strong glass vessel, as a tumbler, or a piece of thick glass tube stopped at one end, with oxygen gas. Invert this also on the shelf of the water bath. When the phosphuretted hydrogen is collected, take the vessel containing it in one hand, and that containing the oxygen in the other; bring the mouth of the former, by sinking it deeper in the water, under the edge of the latter vessel, then by carefully depressing the bottom of the vessel containing the phosphoretted hydrogen, let up a bubble at a time into the oxygen gas. If this experiment is made in a darkened room, the flashes of light appear astonishingly vivid and beautiful. See p. 126.

16. Take six or eight grains of *oxy-muriate of potash*, put it into a mortar and drop in with it about a grain of solid phosphorus, cut into two or three parts; then rub them together with the pestle. Very violent detonations are produced by these small quantities. It is best, therefore, not to use more than is

here mentioned at a time. The hand holding the pestle ought always to be protected with a glove or handkerchief.

17. To make liquid phosphorus, take an ounce vial and half fill it with olive oil, and put into the oil a piece of phosphorus of the size of a pea; gradually heat the bottom of the vial, until the phosphorus is melted, taking care to keep the thumb on the mouth; then cork it air tight. If this vial is first shaken, and then the cork be taken out, it becomes luminous, first near the mouth, and gradually down to the oil, at the bottom. The light which a bottle prepared in this way gives, particularly if warmed, by holding it in the hand, is sufficient to tell the hour of night by a watch. This luminous appearance, when the cork is removed, is owing to the union of the oxygen of the atmosphere with the phosphorus. It is a slow combustion, attended with light, and most probably with some heat.

18. If drawings be made on silk with a solution of nitrate of silver, and the silk first moistened, is exposed to a stream of hydrogen gas, or in any other way exposed to the action of this gas, the metal is instantly revived, and the silk is covered with figures of silver. See p. 147.

19. If a few drops of a solution of nitrate of silver in water, be placed on a bright surface of copper, the silver is revived, and gives the copper a brilliant white coat of that metal. This is explained on the principle of affinity. The copper has a stronger attraction for the acid which composes a part of the nitrate of silver, than the silver itself has. Therefore it attracts the acid from the silver, in consequence of which this is received, and at the same time precipitated on the copper. See p. 147.

20. Take a little of the white arsenic of the shops, and mix it with some finely ground charcoal; put the mixture into a small glass tube closed at one end, and expose the part where the mixture is to a moderate degree of heat gradually raised; the arsenic will be received, and will attach itself to the upper part of the tube, giving it a brilliant metallic coat like quick silver. The arsenic may be preserved in this state by stopping up the tube. See p. 149.

21. Dissolve a teaspoonfull of sugar of lead in a quart of rain water. Put this into a decanter, or white glass bottle, and suspend in it by means of a string a piece of zinc. The zinc decomposes the acetate of lead by depriving it of its oxygen; the consequence is that the lead is precipitated in the metallic state on, and around the zinc, and forms a brilliant tree of metal.

22. Pour a solution of nitrate of silver into a glass vessel

and immerse a few slips of copper in it. In a short time a portion of copper will be dissolved, and all the silver precipitated in a metallic form. If the solution which now contains copper be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated, yielding a striking instance of peculiar affinities. See p. 170.

23. Ivory may be coated with silver by the following process. Make a strong solution of nitrate of silver in pure water; into this immerse a piece of ivory until it turns yellow; then take it out and immediately plunge it into a vessel of distilled water exposed to the direct rays of the sun until it turns black. On rubbing it gently it will appear covered with a brilliant coat of silver, resembling a bar of that metal. This curious effect is owing to the solar light which decomposes the nitrate silver by taking the oxygen from it, which flies off in the form of oxygen gas.

24. Through a vessel of lime water, recently made, pass bubbles of carbonic acid gas by means of a bladder and tube, the lime water instantly becomes white and turbid, and finally deposits a quantity of *carbonate of lime* in the form of powdered chalk. If now the water be evaporated a white powder remains which effervesces with acids. If this powder is put into a retort, and sulphuric acid diluted with water is poured upon it, the beak of the retort being under a vessel filled with water, the carbonic acid is again obtained, and the salt remaining in the retort will be sulphate of lime, or gypsum.

25. Mix one part of *nitric acid* with 5 or 6 parts of water in a vial; into this put some copper filings, and in a few moments pour off the liquid; it will be colourless. If now there be added some liquid ammonia, another colourless fluid, the mixture becomes of an intense and beautiful *blue*. Hence ammonia is a most delicate test for the presence of copper, with which it strikes a deep blue colour. See p. 180.

26. Put into a vial of pure water a few drops of the tincture of nut galls, made by steeping the galls in water; into another vial of pure water put a grain or two of the sulphate of iron. If these colourless fluids are mixed, they instantly become *black*. Tincture of galls is a most delicate test for the presence of iron, with which it strikes a black. These two substances form the basis of ink. See p. 180.

27. Take two small glass jars, or tumblers, and fill one with *carbonic acid gas*, and the other with *oxygen gas*. Have them set upright with a cover on each. If a lighted taper be plunged into the vessel containing the carbonic acid, it is extinguished

instantly; but if it is immediately plunged into the other jar containing the oxygen, it is as instantly lighted with a sort of explosion. See p. 219.

28. Put eight or ten grains of *oxy-muriate of potash* into a teacup, and then pour in two or three drams of alcohol—If now about two drams of sulphuric acid is added, the mixture begins to dart forth little balls of blue fire, and in a minute or two, the whole bursts into flame. The alcohol is inflamed by the clorine which is set free from the salt, in consequence of the combination which takes place between the potash and sulphuric acid. See p. 233.

29. Into a glass tube half an inch or an inch wide, two or three inches long, with a bulb at the end, put a grain or two of iodine. Warm the tube, (but not at that part where the iodine is,) and immediately cork it tight; the tube remains colourless, there being only a few little specks here and there. If at any time the tube be warmed at that part where the iodine is, it is instantly filled with a gas of a most beautiful violet colour. If care is taken to keep the tube well closed, so that the iodine does not escape, when it takes the form of gas, this effect will always be produced whenever the tube is warmed. A tube with two bulbs, like what is called a *pulse glass*, containing the iodine hermetically sealed, would be better. Such a little apparatus would be quite a curiosity to those who know nothing of the nature of iodine. See p. 235.

30. Write on paper with a solution of the nitrat of silver, taking care not to have it so strong as to destroy the paper. So long as it is kept in the dark, or if the paper be closely folded, the writing remains invisible; but on exposure to the rays of the sun the characters turn yellow, and finally black, so that they are perfectly legible.

Mr. Accum says, that this change of colour is owing to the partial reduction of the oxide of silver from the light expelling a portion of its oxygen; the oxide therefore approaches to the metallic state; for when the blackness is examined with a deep, or powerful magnifier, the particles of metal may be distinctly seen.

31. Write on paper with a dilute solution of common sugar of lead; the writing will remain invisible. But on moistening the lines with a pencil, or feather dipped in water impregnated with sulphuretted hydrogen, the metal is revived, and the letters appear in metallic brilliancy.

The author above cited, says, that in this instance, the hydrogen of the sulphuretted hydrogen gas, abstracts the oxygen from the oxide of lead, and causes it to re-approach to the metallic state; at the same time, the sulphur of the sulphuretted hydrogen gas combines with the metal thus regenerated, and converts it into a sulphuret, which exhibits the metallic colour.

32. Write on paper with a solution of the sulphate of copper. If this is strong, the writing will be of a faint green colour; if weak the characters are invisible. On holding the paper over a vessel containing some liquid ammonia, or if it be exposed to the action of this gas in any other way, the writing assumes a beautiful blue colour. On exposing the paper to the sun the colour disappears, because the ammonia evaporates.

33. Put a small piece of phosphorus into a crucible, cover it closely with common chalk, so as to fill the crucible. Let another crucible be inverted upon it, and both subjected to the fire. When the whole has become perfectly red-hot, remove them from the fire, and when cold, the carbonic acid of the chalk will have been decomposed, and the Black Charcoal, the basis of the acid, may be easily perceived amongst the materials.

34. Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of *Sublimation.*

35. Mix a little acetate of lead with an equal portion of sulphate of zinc, both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible: but if they be rubbed together in a mortar, the two solids will operate on each other; an intimate union will take place, and a fluid will be produced. If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful.

36. If the leaves of a plant, fresh gathered, be placed in the sun, very pure oxygen gas may be collected.

37. Put a little fresh calcined magnesia in a tea-cup upon the hearth, and suddenly pour over it as much concentrated sulphuric acid as will cover the magnesia. In an instant sparks will be thrown out, and the mixture will be completely ignited.

38. If a few pounds of a mixture of iron filings and sulphur be made in paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that combustion and flame will be the consequence.

39. For want of a proper glass vessel, a table spoonful of ether may be put into a moistened bladder, and the neck of the bladder closely tied. If hot water be then poured upon it, the ether will expand, and the bladder become inflated.

40. Procure a phial with a glass stopper accurately ground into it; introduce a few copper filings, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state, no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve, and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its colour, which it will recover only by the re-admission of air. These effects may thus be repeatedly produced.

41. If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful green flame.

42. Alloy a piece of silver with a portion of lead, place the alloy upon a piece of charcoal, attach a blow-pipe to a gasometer charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity. This experiment is designed to show the fixity of the noble metals.

43. Burn a piece of iron wire in a deflagrating jar of oxygen gas, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas, this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner. These experiments show the relative combustibility of different substances.

44. Drop a piece of phosphorus about the size of a pea into a tumbler of hot water, and from a bladder, furnished with a stop cock, force a stream of oxygen gas directly upon it. This will afford the most brilliant combustion under water that can be imagined.

45. Take an amalgam of lead and mercury, and another amalgam of bismuth, let these two solid amalgams be mixed by triture, and they will instantly become fluid.

46. Into distilled water drop a little spirituous solution of

soap, no chemical effect will be perceived; but if some of the same solution be added to hard-water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ascertaining the purity of spring water.

47. To silver copper, or brass. Clean the article intended to be silvered, by means of dilute nitric acid, or by scouring it with a mixture of common salt and alum. When it is perfectly bright, moisten a little of the powder, known in commerce by the name of *silvering powder*, with water, and rub it for some time on the perfectly clean surface of copper, or brass, which will become covered with a coat of metallic silver. It may afterwards be polished with soft leather.

The silvering powder is prepared in the following manner: Dissolve some silver in nitric acid, and put pieces of copper into the solution; this will throw down the silver in a state of metallic powder. Take fifteen or twenty grains of this powder, and mix with it two drachms of acidulous tartarite of potash, the same quantity of common salt, and half a drachm of alum. Another method: Precipitate silver from its solution in nitric acid by copper, as before; to half an ounce of this silver, add common salt and muriate of ammoniac, of each two ounces, and one drachm of corrosive sublimate; rub them together, and make them into a paste with water. With this, copper utensils intended to be silvered, that have been previously boiled with acidulous tartarite of potash and alum, are to be rubbed; after which they are to be made red-hot, and polished.

48. To prove that the air of the atmosphere always contains carbonic acid. This may be shewn by simply pouring any quantity of barytic water, or lime water, repeatedly from one vessel into another. The barytic water, when deprived of the contact of air, is perfectly transparent; but it instantly becomes milky, and a white precipitate, which is carbonate of barytes, is deposited, when brought into contact with it for a few minutes only.

The quantity of carbonic acid contained in the atmosphere, seldom varies, except in the immediate vicinity of places where respiration and combustion are going on in the large way, and is about one hundredth part.

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TABLE OF THE EFFECTS OF HEAT.

1. FREEZING POINTS OF LIQUIDS.

Fahrenheit.	
— 55	Strongest nitric acid freezes (Cavendish)
46	Ether and liquid ammonia
39	Mercury
36	Sulphuric acid (Thompson)
22	Acetous acid
11	2 Alcohol, 1 water
7	Brandy
+ 1	Strongest sulphuric acid (Cavendish)
16	Oil of turpentine (Macquer)
20	Strong wines
23	Fluoric acid
	Oils bergamot and cinnamon
25	Human blood
28	Vinegar
30	Milk
32	Oxymuriatic acid
	Water
36	Olive oil
46	Sulphuric acid, specific gravity 1.78 (Keir)
64	Oil of anniseeds, 50 (Thompson)

2. MELTING POINTS OF SOLIDS.

40	Equal parts of sulphur and phosphorus
82	Adipocire of muscle
97	Lard (Nicholson)
90	Phosphorus
104	Resin of bile
109	Myrtle wax (Cadet)
112	Spermaceti (Bostock)
127	Tallow (Nicholson) 92 (Thompson)
149	Bees' wox
145	Ambergris (La grange)
155	Bleached wax (Nicholson)
212	Bismuth 5 parts, tin 3, lead 2

Fahren.	Wedg.	
234		Sulphur (Hope) 212 (Fourc.) 185 (Kirw.)
235		Adipocire of biliary calculi (Fourcroy)
383		Tin and bismuth, equal parts
303		Camphor
334		Tin 3, lead 2, or tin 2, bismuth 1
442		Tin (Chrichton) 413 (Irvine)
460		Tin 1, lead 4
476		Bismuth (Irvine)
612		Lead (Crichton) 594 (Irv.) 540 (Newton)
680		Zinc
809		Antimony
3809	21	Brass
4587	27	Copper
4717	22	Silver
5237	32	Gold
17977	130	Cobalt
20577	150	Nickel
21097	154	Soft nails
21637	158	Iron
21877	160	Manganese
23177	+170	Platinum, tungsten, molybdena, uranium, titanium, &c.

3. SOLIDS AND LIQUIDS VOLATILIZED.

98		Ether boils
140		Liquid ammonia boils
145		Camphor sublimes (Venturi)
170		Sulphur evaporates (Kirwan)
176		Alcohol boils, 174 (Black)
212		Water and essential oils boil
219		Phosphorus distils (Pelletier)
230		Muriate of lime boils (Dalton)
242		Nitrous acid boils
248		Nitric acid boils
283		White arsenic sublimes
540		Metallic arsenic sublimes
554		Phosphorus boils
560		Oil of turpentine boils, about 212° (Dalton)
570		Sulphur boils
590		Sulphuric acid boils (Dalton) 546 (Black)
600		Linseed oil boils, sulphur sublimes (Davy)
660		Mercury boils (Dalton) 644 (Secondat) 600 (Black) 672 (Irvine)

4. MISCELLANEOUS EFFECTS OF HEAT.

Fahren.	Wedg.	
— 90		Greatest cold produced by Mr. Walker
50		Natural cold produced at Hudson's Bay
23		Observed on the surface of the snow at Glasgow, 1780
14		At Glasgow, 1780
0		Equal parts, snow and salt
+ 43		Phosphorus burns slowly
59		Vinous fermentation begins
66		to 135 Animal putrefaction
75		to 80 Summer heat in this climate
77		Vinous fermentation rapid, acetous begins
80		Phosphorus burns in Oxygen, 104 (Gottling)
88		Acetification ceases
96		to 100 Animal temperature
107		Feverish heat
122		Phosphorus burns vividly (Fourcroy) 148 (Thomson)
165		Albumen coagulates, 156 (Black)
303		Sulphur burns slowly
635		Lowest heat of ignition of iron in the dark
800		Hydrogen burns, 1000 (Thomson)
802		Charcoal burns (Thomson)
1050		Iron red in twilight
1207	1	Iron red in day light
1337	+ 2	Azotic gas burns
1857	6	Enamel colours burned
2897	14	Diamond burns (M'Kenzie) 30 W. = 5000 F (Morveau)
6277	40	Delft ware fired
8487	57	Working heat of plate glass
10177	70	Flint glass furnace
12257	86	Cream-coloured ware fired
13297	94	Worcester china vitrified
14337	102	Stone ware fired
14727	105	Chelsea china fired
15637	112	Derby china fired
15897	114	Flint glass furnace greatest heat
16007	121	Bow china vitrified
16807	124	Plate glass greatest heat
17327	125	Smith's forge
20577	150	Hessian crucible fused
25127	185	Greatest heat observed

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